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National Facilities Study

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Volume 3 – Mission and Requirements Report

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Section 1

Executive Summary

1.1 Background

The National Facility Study (NFS) was initiated in 1992 by Daniel S. Goldin, Administrator of the National Aeronautics and Space Administration (NASA), as an initiative to develop a comprehensive and integrated long-term plan for future facilities. In November, 1992, Administrator Goldin proposed to Deputy Secretary of Defense, Donald J. Atwood, that the Department of Defense (DoD) join the NFS to "allow us to impact external budget submissions, as appropriate...to ensure...the proper infrastructure for our nation's aerospace industry to remain the world's leader." In December, 1992, Secretary Atwood agreed to join the NFS and made the "recommendation that the Department of Commerce be added." The resulting, multi-agency NFS consisted of three Task Groups:

- Aeronautics Task Group
- Space Operations Task Group
- Space Research and Development (R&D) Task Group.

A fourth group, the Engineering and Cost Analysis Task Group, was subsequently added to provide cross-cutting functions, such as assuring consistency in developing an inventory of space facilities.

Space facilities decisions require an assessment of current and future needs. Therefore, the two task groups dealing with space developed a consistent model of future space mission programs, operations and R&D.

1.2 Baseline Model

The model is a common, conservative baseline constructed for NFS analytical purposes with excursions to cover potential space program strategies. (As agency and Administration decisions impacting the mission model are made, the model will be updated to reflect those decisions.) The model includes three major sectors: DoD, civilian government (e.g., NASA, NOAA, etc.), and commercial space (e.g., the telecommunications satellite industry). The model spans the next 30 years because of the long lead times associated with facilities development and usage. (Of course, longer term projections clearly have greater uncertainty than nearer term features of the model.)

The DoD members of the Space Operations and R&D Task Groups developed the military elements of the requirements model. NASA members of the task groups integrated the civilian government portion. Commercial space requirements were provided by DOT's Office of Commercial Space Transportation using inputs from the Commercial Space Transportation Advisory Committee. For each sector, a baseline forecast of future missions, supporting programs (e.g., R&D), and launch requirements was developed and integrated for the period 1993-2023. The goal of the baseline was to provide a common, conservative basis for facilities requirements, analysis, and recommendations. In addition to this baseline, a set of 'excursions' was also defined to test the sensitivity of facility recommendations to the mission model.

Selected, significant baseline features are summarized in the paragraphs that follow.

1.2.1 Commercial Space Baseline

The baseline model for civilian commercial space activities includes continuing manufacture, launch, and operations of existing systems (with periodic block upgrades), augmented by selected major systems developments. Areas included:

- Launch Systems. The model forecasts (a) continuing operation of existing commercial expendable launch vehicle fleets through 2023; and, (b) development of a new family of small payload low-cost ELVs after 1998.

- Telecommunications. The model forecasts (a) continuing operations of RF geostationary telecommunications satellite systems, with block upgrades to 2023; and, (b) after 1995-1998, initiation of 1-2 LEO telecommunications constellations, with block upgrades through 2023.

- Earth Observing / Remote Sensing. The baseline includes modest commercial Earth remote sensing satellite operations following 2003.

- Materials Processing In Space,. The forecast is for modest commercial materials processing operations following 2003.

1.2.2 Civilian Government Space Baseline

The baseline model for civilian government space activities forecasts continuing operations of existing systems as well as several major new systems developments after 2000-2005. In addition to ongoing mission-supporting manufacturing (e.g., in industry), launch (e.g., KSC) and operations (such as the DSN), baseline areas include:

- Mission to Planet Earth / Earth Observing. The forecast calls for (a) completion of the initial Earth Observing System series; development & operations of a second series through 2023 with small to medium size platforms; and, (b) NOAA weather satellite systems (and upgrades).

- Space Science/Mission From Planet Earth. The model includes (a) completion of the 'Great Observatories'; followed by small & moderate-class Earth orbit science missions; and, (b) a strategic changeover to small to moderate-class deep space probes after the launch of the flagship-class Cassini mission to Saturn.

- Space Exploration and Development. The baseline includes (a) Space Shuttle operations (w/ upgrades) and the current expendable launch vehicles (with upgrades) through the 2023 timeframe; (b) development and launch of international redesigned space station with European, Japanese, Canadian and Russian elements and U.S. launch, with continuing operations through the 2023 timeframe; and, (c) phased transition of the Deep Space Network (DSN) to Ka-Band communications in 2003-2008.

- Space Technology. Programs will include mission-supporting R&D, such as (a) selected NASA technology flight experiments (on Shuttle, station, etc.); and (b) NASA R&D programs (including power, propulsion, small spacecraft, etc.).

1.2.3 Baseline Department of Defense Requirements

The baseline requirements model for DoD space activities includes continued operation and block upgrades of major DoD space systems and some new systems developments in the post-2000 time-frame, as well as R&D to prepare for future systems deployment decisions. Areas include:

- Communication and Navigation. The forecast includes (a) Military Satellite Communications systems operations and block upgrades; and, (c) operations of current NAVSTAR Global Positioning System.

- Surveillance / Earth & Weather Observing. The baseline projects (a) development and deployment of Early Warning Systems (including DSP); (b) launch and operation of GEOSat Follow-On (GFO) mission; and, (c) development, deployment and operations of Defense Meteorological Satellite Program (DMSP) systems.

- Missile Offense and Launch Systems. The model projects (a) continuing ICBM Systems operations and upgrades; and (b) operations and upgrades of current launch Systems, including current vehicles and ground infrastructure).

- Technology Development and Flight Experiment Programs. The forecast includes supporting programs, such as (a) R&D areas and/or programs); and, (b) technology flight programs.

- Classified Mission and Programs Appropriate for the Baseline.

1.2.4 U.S. Launch Capabilities Summary Assessment

Each of the three sectors will require significant yearly space launch operations, with the predominant utilization of West coast facilities by the DoD, and mixed use of East coast facilities.

1.3 Excursions from the Baseline

In addition to the baseline model, a series of excursions was developed for both space task groups. For the Space Operations Task Group, a single excursion was developed (examining the impact of a future decision to develop a new highly reusable vehicle (HRV) for access to space (such as a Single-Stage-to-Orbit, SSTO, vehicle). For the Space R&D Task Group, three broad options were considered, including the development of several significant new systems in the post-2000 time-frame in all three sectors, paralleled by increasing support to U.S. industry by related (predominantly civilian) government space R&D programs. For example, in commercial space a new cargo-carrying vehicle was projected, to serve projected growth in low Earth orbit (LEO) communications systems, in commercial Earth observing and/or remote sensing, and in materials processing in space (beginning in the post-2003 time-frame).

Similarly, in the civilian government sector, the excursions forecast new systems for Mission to Planet Earth (e.g., geostationary platforms following completion of the initial EOS), for Space Science (such as Next Generation Space Observatories in post-2008), for Human Exploration and Space Development (such as replacement of the Shuttle by an HRV), as well as growth in space technology efforts in ground-based R&D and technology flight experiments. Finally, for DoD, excursion projections included launch and operations of GPS II for improved navigation, new multispectral Surveillance Systems, a Next Generation Launch System, potential deployment of Missile/Theater Defense Systems, and classified missions and programs appropriate for the excursion.

1.4 Description of this Report

1.4.1 NFS Report Context

The final report of the NFS is organized in five volumes:

- Volume 1 – the NFS computerized facility inventory,
- Volume 2 – the Aeronautics R&D Task Group final report,
- Volume 3 – the mission and requirements model used by the NFS space task groups,
- Volume 4 – the Space Operations Task Group final report, and
- Volume 5 – the Space R&D Task Group final report.

1.4.2 Organization of this Document

This document, Volume 3 of the NFS report, is organized along the following lines:

- Section 1
  Executive Summary, provides a summary view of the 30-year mission forecast and requirements baseline, an overview of excursions from that baseline that were studied, and organization of the report.

- Section 2
  Introduction, provides discussions of the methodology used in this analysis.

- Section 3
  Baseline Model, provides the mission and requirements model baseline developed for Space Operations and Space R&D analyses.

- Section 4
  Excursions from the baseline, reviews the details of variations or 'excursions' that were developed to test the future program projections captured in the baseline.

- Section 5
  Glossary of Acronyms.

In addition, several appendices are included (e.g., references, and details of launch projections).

1.4.3 Disclaimers and Limitations

The requirements model developed for the NFS is a 'middle-ground' baseline constructed for analytical purposes with excursions to cover potential space program strategies. As Agency and Administration decisions impacting the model are made, the model will be updated to reflect those decisions. This report is intended for use by NFS working groups in analyzing options for keeping, closing, or building space research and development (R&D) facilities. This report is designed to serve as a forum for presenting and stimulating innovative thinking on government agencies' missions, doctrine, strategy, infrastructure, requirements and other national space R&D matters. The views and opinions expressed or implied in this report are those of the authors and should not be construed as carrying the official sanction of any Agency of the US Government.

Section 2
Introduction

2.1 Background

The National Facility Study (NFS) was initiated in 1992 by Daniel S. Goldin, Administrator of the National Aeronautics and Space Administration (NASA), as an initiative to develop a comprehensive and integrated long-term plan for future facilities. In November, 1992, Administrator Goldin proposed to Deputy Secretary of Defense, Donald J. Atwood, that the Department of Defense (DoD) join the NFS to "allow us to impact external budget submissions, as appropriate...to ensure...the proper infrastructure for our nation's aerospace industry to remain the world's leader." In December, 1992, Secretary Atwood agreed to join the NFS and made the "recommendation that the Department of Commerce be added." The resulting, multi-agency NFS consisted of three Task Groups:

- Aeronautics Task Group
- Space Operations Task Group
- Space Research and Development (R&D) Task Group.

A fourth group, the Engineering and Cost Analysis Task Group, was subsequently added to provide cross-cutting functions, such as assuring consistency in developing an inventory of space facilities.

Space facilities decisions require an assessment of current and future needs. Therefore, the two task groups dealing with space developed a consistent model of future space mission programs, operations and R&D. The model is a middle ground baseline constructed for NFS analytical purposes with excursions to cover potential space program strategies. (As agency and Administration decisions impacting the mission model are made, the model will be updated to reflect those decisions.) The model includes three major sectors: DoD, civilian government (e.g., NASA, NOAA, etc.), and commercial space (e.g., the telecommunications satellite industry). The model spans the next 30 years because of the long lead times associated with facilities development and usage. (Of course, longer term projections clearly have greater uncertainty than nearer term features of the model.)

The DoD members of the Space Operations and R&D Task Groups developed the military elements of the requirements model. NASA members of the task groups integrated the civilian government portion. Commercial space requirements were provided by DOT's Office of Commercial Space Transportation using inputs from the Commercial Space Transportation Advisory Committee. For each sector, a baseline forecast of future missions, supporting programs (e.g., R&D), and launch requirements was developed and integrated for the period 1993-2023. The goal of the baseline was to provide a common, conservative basis for facilities requirements, analysis, and recommendations. In addition to this baseline, a set of 'excursions' was also defined to test the sensitivity of facility recommendations to the mission model.

2.2 Relationship between the Space R&D, Space Operations and Aeronautics Facilities Task Groups

The focus of the requirements definition effort in support of the Space R&D Task Group was to model the future systems engineering, research and development requirements for space systems over the next 30 years. The focus of the requirements definition effort in support of the

Space Operations Task Group Facilities study is on launches and launch facilities, with additional effort to assure coverage of other operations facilities, such as telecommunications and mission operations.

There is a relationship between Space R&D and Space Operations in that those launches driven by research and development work are included in the National Launch Model developed jointly by AFSPACECOM, DOT, and NASA. (AFSPACECOM represented all DoD interests in launch, and developed a schedule that more than adequately covers all known and projected launch requirements to support DoD R&D needs for the next 30 years.)

Finally, the primary coordination with the Aeronautics R&D Facilities Study was in the context of hypersonics research facilities.

2.2 Requirements Model Methodology

The requirements model provides for three parallel and interwoven components, corresponding to the three major U.S. sectors engaged in space R&D: the DoD, civilian government space (e.g., NASA, NOAA, etc.), and civilian commercial space (e.g., the telecommunications satellite industry). The methodology, which is illustrated in Figure 1, produced a 30-year projection (with excursions) of future U.S. space activities.

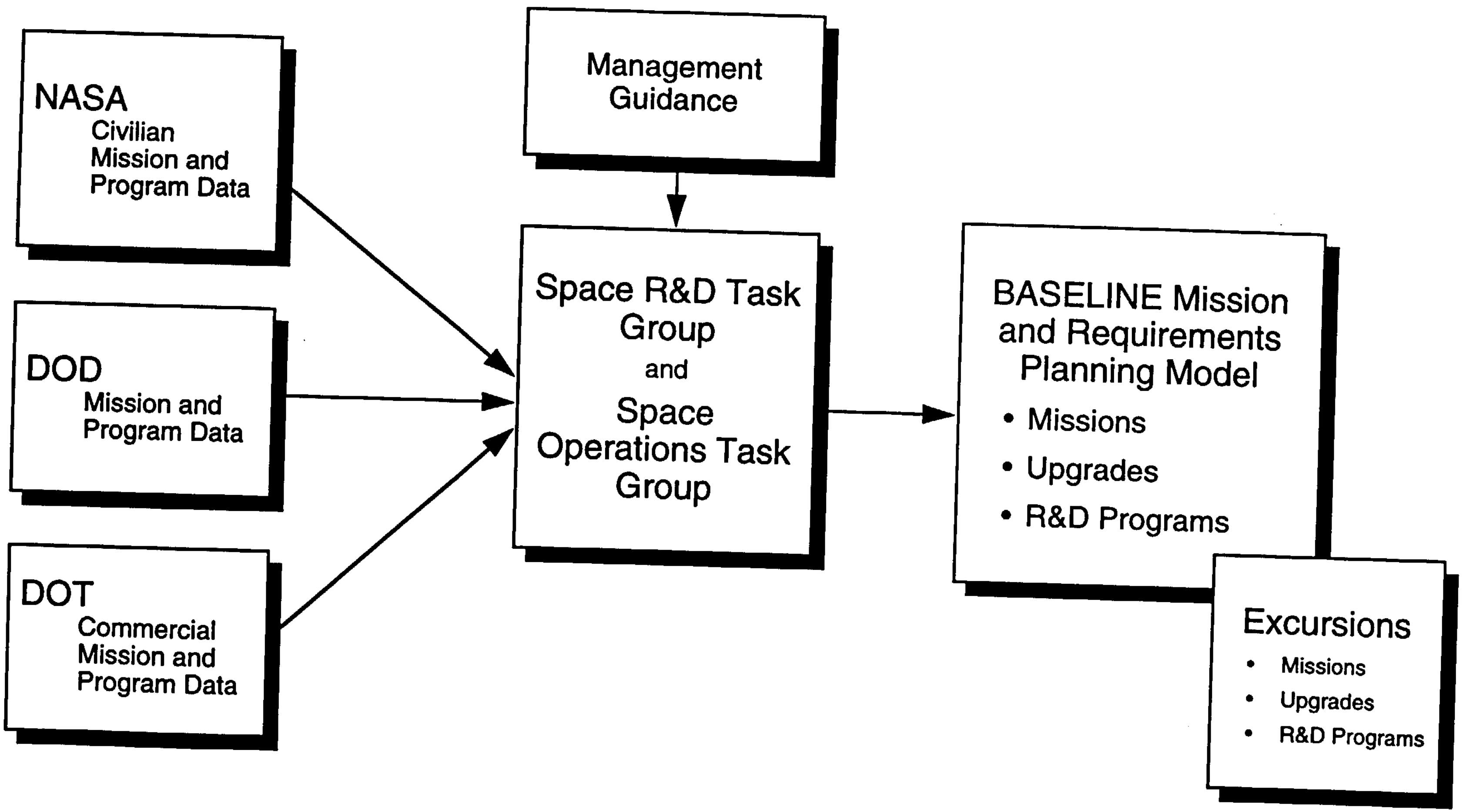
2.2.1 Baseline Mission Model Methodology

The baseline commercial space requirements model was developed by the Department of Transportation (DOT) Office of Commercial Space Transportation (OCST) using inputs from the OCST Commercial Space Transportation Advisory Committee (COMSTAC), an industry group. The overall methodology used by the OCST and COMSTAC included industry-derived market assessments (competitor evaluations) in the areas of telecommunications, launch systems and emerging areas (i.e., commercial remote sensing and in-space materials processing), and certain key assumptions regarding future commercial space activities. Current and projected space systems providing commercial telecommunications services, such as GEO communications satellites and new LEO satellite constellations were the primary focus of the assessment. For each area, a forecast of future launch requirements and rates was developed and integrated, specific future mission targets were identified over time. The baseline assessment assumed that the current fleet of U.S. launch vehicles would be upgraded through significant improvements in component technologies during the period of interest (1993 to 2023).

Civilian government space activities were divided into four categories: Mission to Planet Earth/Earth Observing, Space Science, Space Exploration and Development, and Space Technology. The baseline model was developed through a five-step process: (1) literature research (drawing on past and ongoing planning and studies); (2) discussions with appropriate program offices representatives to clarify specific points within the model; (3) coordination with NFS Space Operations Task Group mission model activities; and, (4) review and discussion with NASA strategic planning teams.

The national security space activities baseline requirement model was developed through updating the projected space launch needs missions model which integrates the needs of the three services (USAF, USN and USA) and other national security agencies. These space launch needs are driven by operational requirements in four broad area: communication and navigation,

Figure 1 – NFS Space Mission and Requirements Model Development Process



surveillance/Earth and weather observing, missile offense and launch systems, and technology development and flight experiment programs.

2.2.2 Baseline Mission Model Upgrades and Support R&D Programs Methodology

To support the space R&D facilities assessment, additional information regarding plans for new systems and upgrades, as well as technology development programs for future missions was collected. For the commercial space sector, this information was obtained from the DOT. For the civilian government sector, this information was obtained from ongoing program planning efforts and from agency strategic planning activities. The DoD approach was based on the belief that beyond the near-term (next six years) planning for technology must be based upon expected technology shortfalls in meeting operational requirements. The DoD methodology was a six step approach, including: (1) Determination of Mission Need; (2) development of Mission Plans; (3) development of specific System Plans; (4) development of detailed Subsystem Plans; (5) formulation of supporting Technology Plans; and, (6) definition of needed Facility Plans.

2.2.3 Excursions Methodology

The methodology used to develop commercial space excursions closely paralleled that used for the baseline model. The assessment of excursions from the commercial space baseline was intended to capture possible increases in requirements resulting from higher-than-anticipated demand or new technologies that might alter the market. These increases in requirements were found to be consistent with the development of a new ELV offering reduced launch costs, but did not reflect the dramatically lower costs that might result from a major new launch technology (such as an HRV). The commercial space excursions were in turn coordinated with necessary changes and adjustments in space R&D program requirements in NASA to support increases in commercial space activities, following on the National Advisory Committee on Aeronautics (NACA) model as an example.

The methodology used for developing position excursions from the civilian government space baseline model was virtually identical with that used for the development of the baseline. Additional literature sources were tapped, including mission forecasts and plans developed in the recent past, which were adapted and adjusted in accordance with ongoing changes in program and budget ground rules (e.g., the movement toward smaller spacecraft in future missions).

The historical planning methodology used within the laboratory community encourages technology-push projects and programs. Planning for technology-push programs has inherently long-term strategic goals and objectives.

2.3 Model Overview

For the NFS, space missions are sorted by the sector (civilian commercial, civilian government, and military) and then by baseline and emphasis excursions.

<u>The Baseline</u>. The baseline is the three groupings of currently on-going, planned and projected programs and projects of each of the three sectors. To be in the baseline the programs and projects must meet the following criteria:

1. Activities that are in the President's 1994 Budget as submitted (or amended),

2. Future projected activities that are consistent with the President's 1994 Budget, and recent organizational strategic planning,

3. Any recent national-level decisions that are very likely to be reflected in the 1995 President's program.

Excursions from the Baseline. The excursions or emphasis missions are those programs desirable by each "owner," but that are currently out-of-scope, in whole or part, of the current President's 1994 Budget. These programs are in the research, development, or demonstration phase of the acquisition life cycle and have not been given approval to go into production or deployment. However, from at bottoms up approach, these are the missions each organization would execute if funding permitted.

The following paragraphs provide top-level summaries of the mission requirements model by sectors, for both the baseline and positive excursions from the baseline. Further details of each broad area mission is found in the Sections 3 and 4 of this report.

2.3.2 Baseline Mission and Requirements Model

2.3.2.1 Commercial Space -- Baseline

The baseline requirements model for commercial space activities includes four broad areas: launch systems, telecommunications, Earth observing and remote sensing, and in-space materials processing. The components of the model within these areas are summarized below.

General: selected major new system developments will take place.

Specific Mission/System/Program Elements, including:

1. Launch Systems
   A. Continuing operation of existing commercial expendable launch vehicle fleets through 2023
   B. Development of a new family of small payload low-cost ELVs after 1998

2. Telecommunications
   A. Continuing operations of RF geostationary telecommunications satellite systems, with block upgrades through 2023
   B. post 1995-1998, initiation of 1-2 low Earth orbit telecommunications satellite constellations, with block upgrades through 2023

3. Earth Observing / Remote Sensing
   A. Modest commercial Earth remote sensing satellite operations following 2003

4. Materials Processing In Space
   A. Modest commercial materials processing operations following 2003

2.3.2.2 Civilian Government Space -- Baseline

The baseline requirements model for civilian government space activities also includes four broad areas: Mission to Planet Earth (MTPE) / Earth Observing, Space Science / Mission From Planet Earth (MFPE), Space Exploration and Development, and Space Technology. These areas parallel four of the five 'strategic enterprise' areas into which NASA's FY 1993-1994 strategic planning activities are organized. (The fifth NASA strategic enterprise area, Aeronautics

Technology, is not germane to the space requirements model.) The components of the model within these ares are summarized below.

General: several major new system developments after 2000-2005.

Specific Mission/System/Program Elements, including:

1. Mission to Planet Earth / Earth Observing
   A. Complete initial Earth Observing System series; develop & operate a small to moderate scale platform second series through 2023
   B. NOAA Operations of Weather Satellite System(s), with upgrades

2. Space Science/Mission From Planet Earth
   A. Completion of the 'Great Observatories' (HST, C-GRO, AXAF (I and S), SIRTF); followed by small & moderate-class Earth orbit science missions (e.g., AIM)
   B. Changeover to small to moderate-class deep space probes for post-Cassini (e.g., Pluto FFB, MESUR P/F, MESUR Network, NEAR, etc.)

3. Space Exploration and Development
   A. Space Shuttle operations (w/ upgrades) and the current expendable launch vehicles (with upgrades) through' 2023 timeframe
   B. Development and launch of international redesigned space station with European, Japanese, Canadian and Russian elements and U.S. launch, with continuing operations through' 2023 timeframe
   C. Phased Transition of the DSN to Ka-Band communications in 2003-2008

4. Space Technology
   A. Selected NASA technology flight experiments (on Shuttle, station, etc.)
   B. NASA R&D programs (including power, propulsion, small spacecraft, etc.)

2.3.2.3 Department of Defense -- Baseline (Requirements-Pull)

The baseline requirements model for DoD space activities includes five broad areas: communications and navigation, surveillance and Weather observing, missile offense and launch systems technology development and flight demonstrations, and classified missions. The components of the model within these areas are summarized below.

General, including (1) some new system developments in the post-2000 time-frame, and (2) research and development programs to prepare for future systems deployment decisions.

Specific Mission/System/Program Elements, including

1. Communication and Navigation
   A. Military Satellite Communications systems operations and block upgrades (including: AFSATCOM, DSCS-III, UFO, MILSTAR, and Polar Communication Satellite),
   B. Operations of current NAVSTAR Global Positioning System,

2. Surveillance / Earth & Weather Observing
   A. Early Warning Systems (including DSP and FEWS),
   B. Development, deployment and operations of Defense Meteorological Satellite Program (DMSP) systems (e.g. Block VI),
   C. Launch and operation of GEOSat Follow-On (GFO) mission,
   D. LANDSAT

3. Missile Offense and Launch Systems
    A. Continuing ICBM Systems operations and upgrades (including the Minuteman life extension program, D-5 (Trident), and Rapid Execution and Combat Targeting, REACT),
    B. Launch Systems, including current vehicles (e.g. Pegasus, Delta, Atlas, and Titan, plus improvements to vehicles and ground infrastructure)

4. Technology Development and Flight Experiment Programs
    A. Technology R&D areas/programs (including: Astronics, GN&C, Power, Propulsion, Structures, Survivability, and Thermal Management and Control),
    B. Technology flight programs (including: ARPA & BMDO missions, Clementine I & II, Space Test Program, TAOS, TOPAZ, etc.),

5. Classified mission and programs appropriate for the baseline

2.3.3 Current U.S. Launch Capability

The current U.S. launch capability includes the following launch systems: the Space Shuttle, the Titan family of vehicles, the Atlas family of vehicles, the Delta family of vehicles, and a number of small launch systems such as Pegasus, Taurus and the new Lockheed small launch vehicle. (Additional information regarding current U.S. launch capability and requirements is provided in Appendix D.)

2.3.3.1 Space Shuttle

The Space Shuttle uniquely support the nation's piloted space activities, supports on-orbit activities for periods of up to 2 weeks, and provides a return-from-space cargo capability. The Space Shuttle is launched from the Kennedy Space Center and involves four major flight elements, including: the orbiter, Space Shuttle main engine, solid rocket boosters, and external tank. The orbiter, main engine, and solid rocket boosters are reused while the external tank is expended during each flight. NASA plans to use the Space Shuttle for the next thirty years, with a planned flight rate capability of eight per year using two launch pads located at KSC in Florida. There are four orbiters and no plans to manufacture additional orbiters.

2.3.3.2 Titan Family

The Titan IV launch system is the nation's largest cargo-only launch capability and is considered the U.S. workhorse for launch national security payloads. The Titan IV system is operational at the Eastern Test Range (ETR) and the Western Test Range (WTR) and involves two major flight elements: the core vehicle and strap-on solid rocket boosters. The Titan IV launch infrastructure includes two launch pads at the ETR, supporting a projected flight rate of up to four flights per year, and one launch pad at the WTR, supporting a projection of two flights per year. The Centaur upper stage vehicle is used in conjunction with the Titan IV for large payloads destined to intermediate or geosynchronous Earth orbit (GEO), and for high energy planetary missions.

The Titan II vehicle flight hardware results from the refurbishment of missiles previously stored in silos for use in launching to Earth orbit. The Titan II is launch from the WTR and is projects to have a capability of three per year from a single launch pad. Titan II and Titan IV operational activities are somewhat interdependent and the actual Titan II capability can be decreased by Titan IV activities.

2.3.3.3 Atlas Family

The Atlas launch system is an intermediate capability launch vehicle. The basic launch vehicle is a two-stage vehicle using liquid propulsion for each stage: liquid oxygen/hydrocarbon for the booster stage, and liquid oxygen/hydrogen for the upper (Centaur) stage. A recent growth configuration includes four castor solid rocket motors attached to the booster stage. The Atlas launch infrastructure includes two launch pads at the ETR and one launch pat the the WTR. The USAF projects an Atlas flight rate capability of nine flights per year at the ETR and four flights per year at the WTR.

2.3.3.4 Delta Family

The Delta launch system is medium capability launch vehicle. The first stage is powered by a liquid oxygen/kerosene engine, the second stage by a liquid storable propellant engine, and the third stage by a solid rocket motor. Additional thrust augmentation is provided by nine caster solid rocket motors attached to the first stage. The Delta launch infrastructure includes two launch pads a the ETR, and one pad at the WTR. The USAF projects a combined ETR/WTR flight rate capability of ten flights per year. Most of the launch crew for the Delta is based at the ETR and the crew is deployed on a temporary basis to support WTR launches, as required.

2.3.3.5 Small Launch Vehicles

Pegasus. The Pegasus launch system is a small capability ELV. It is a three-stage, solid propellant winged vehicle used to place small, low-cost payloads into space inexpensively. Pegasus is carried aloft by a conventional transport/bomber-class aircraft. After release from the carrier aircraft and first sage motor ignition, the vehicle follows an optimal lifting direct ascent trajectory to orbit. Pegasus launches are based at NASA's East coast Wallops Flight Station. Launch rates are constrained primarily by range scheduling only.

Taurus. The Taurus launch system is also a small capability ELV. The Taurus vehicle configuration is derived from Pegasus and Peacekeeper stages. The vehicle is a four-stage, solid propellant vehicle. The vehicle is fully transportable allowing for rapid launch site establishment compatible with both ETR and WTR ranges. Initial launch operations are planned at the WTR, with projected flight rates of up to 12 launches per year.

Other commercially-development, small launch vehicles (SLVs) include the Conestoga, the Lockheed SLV, and the Comet. These are all in various stages of development and initial operations.

2.3.4 Excursions from the Baseline

2.3.4.1 Commercial Space -- Emphasis/Excursions

The excursions from the baseline requirements model for civilian commercial space activities follows the same four broad areas as the baseline; these excursions are summarized below.

General, with (1) several significant new system developments in the post-2000 time-frame in the Commercial Space Sector, and (2) Increasing support with U.S. industry in government space research and development programs.

Specific Mission/System/Program Elements, including:

1. Launch Systems
Development of new non-piloted cargo vehicle for commercial space applications (with operations in the 2004-2008 time-frame; potential fully reusable)

2. Telecommunications
Augmented commercial LEO communications systems and other space-derived services (e.g. global positioning)

3. Earth Observing / Remote Sensing
Transition of continuation of selected EOS data sets to provide sector suppliers

4. Materials Processing In Space
Increased commercial materials processing and manufacturing operations beginning in the post-2003 time-frame.

2.3.4.2 Civilian Government Emphasis/Excursions

The excursions of the requirements model for civilian government space activities follows the same four broad areas. These components of the excursion are summarized below.

General, including (1) several significant new system developments in the post-2000 time-frame, (2) increasing technology content and required R&D for flight programs, and (3) increasing involvement with U.S. industry in R&D programs.

Specific Mission/System/Program Elements, including

1. Mission to Planet Earth / Earth Observing
A. Complete initial Earth Observing System series; to small- to moderate- platform second series; with selected low-cost Geostationary platforms in after 2008,
B. NOAA Operation of integrated Earth/Weather remote sensing systems,

2. Space Science/Mission From Planet Earth
A. Major-science/moderate-cost Next Generation Space Observatories in post-2008 (e.g.,TOPS-2),
B. Intensive robotic solar system exploration (in situ with selected sample return),

3. Space Exploration and Development
A. Phase-out operation of Space Shuttle in the 2005 time-frame; early replacement with Highly Reusable Vehicle (HRV) for crew and cargo (Access to Space Option 3-class),
B. Development and operations of international redesigned space station, through 2014 time-frame, then evolution of program with new elements and continuing international participation,
C. DOT/FAA operation of jointly-managed follow-on GPS constellation,
D. Evolution of Telecommunications/DSN with optical communications,
E. Lunar Outpost development in 2013-2018 (including HLLV development), with Human Mars Missions preparation in 2014-2023 time-frame.

4. Space Technology
Increased ground-based R&D and technology flight experiments to support mission programs listed above.

2.3.4.3 Department of Defense -- Emphasis/Excursions (Technology-Push)

The DoD space excursions requirements model represent 'technology push' opportunities within the same five broad areas used for the baseline, with an additional area, "aerospace control". The components of the excursion within these areas are summarized below.

General, with several significant additional new system developments in the post-2000 time-frame.

Specific Mission/System/Program Elements, including

1. Communication and Navigation
   A. Launch and operations of GPS II constellation
   B. UHF Follow-On (UFO) replacement

2. Surveillance / Earth & Weather Observing
   A. Deployment and operations of Global Theater Surveillance System(s) (including: Brilliant Eyes (post 2000+), Visible Light System I & II, and Tactical Support System)
   B. Development of deployment and operations of advanced LANDSAT
   C. Development of new multispectral Surveillance Systems

3. Missile Offense and Launch Systems
   A. Development of Next Generation Launch System, (NLS-derived or reusable non-piloted cargo vehicle for military space applications) with operations in the 2005 time-frame), accompanied by phase-out of current ELVs,

4. Technology Development and Flight Experiment Programs
   A. Technology R&D areas/programs (including: Astronics, GN&C, Power, Propulsion, Structures, Survivability, and Thermal Management and Control),

5. Aerospace Control
   A. Deployment and operations of Missile/Theater Defense Systems (TDS) (e.g., post-1996+: TMD(I), and post-2000+: Air Borne Laser (ABL), (TMD), Space Based Laser (SBL), Space Based Interceptor (SBI).

6. Classified mission and programs appropriate for the excursion.

Section 3

Baseline Mission Model

3.1 Overview

3.1.1 Mission Sectors

The goal of the mission and requirements model efforts (in the Space R&D and Space Operations Task Groups) was to provide the latest operational mission objectives and schedules, planned upgrades to missions, and relevant information on supporting R&D programs. In order to simplify the problem for the NFS, the Space R&D and Space Operations requirements teams organized all known national space mission and R&D programs into a matrix of mission sector verses category of missions. The three sectors into which missions were organized included:

- Military Activities (M-)
- Civilian Government (Cg-)
- Commercial Space (Cs-)

Figure 2 illustrates this matrix at a summary level for the baseline mission and requirements model. The responsibility for developing requirements of the various space R&D programs were divided among several organizations, including Military Activities (M-): DoD responsibility for military space, NASA responsibility for civilian government space, and DOT responsibility for collecting industry inputs, with NASA integration of overall civilian requirements.

3.1.2 Requirements Categories

The programs underneath each "sector" were further divided into one of six categories:

1. Primary Missions (M-1); these requirements were used by both Space Operations and Space R&D Task Groups.

2. Scheduled Upgrades (U-1); these requirements were used by the Space R&D Task Group.

3. Current or planned mission-supporting R&D Programs (P-1); these requirements were used by the Space R&D Task Group.

4. Excursion/Emphasis Missions (M-2); these requirements were used by the Space R&D Task Group (with the exception of the development of a new SSTO vehicle, which was also used by the Space Operations Task Group).

5. Excursion/Emphasis Upgrades (U-2); these requirements were used by the Space R&D Task Group.

6. Excursion/Emphasis R&D Programs (P-2); these requirements were used by the Space R&D Task Group.

Thus, there are 18 possible sector/category groupings by which the requirements were organized (three sectors and 6 categories for each sector). Figure 3 depicts this full, detailed matrix of alternatives and identifies which cases were studied as part of the NFS.

Figure 2 – NFS Space Mission and Requirements Baseline Model Overview

	Military Activities	Civilian Government	Commercial Space
BASELINE MISSIONS	$\boxed{\text{Moderate Projection of Military Space Missions During the 1993-2023 Timeframe (MM-1)}}$	$\boxed{\text{Moderate Projection of Civil Government Space Missions During the 1993-2023 Timeframe (CgM-1)}}$	$\boxed{\text{Moderate Projection of Commercial Space Missions During the 1993-2023 Timeframe (CsM-1)}}$
Upgrades to Baseline Missions/ Systems	Projected upgrades to current Military Space systems/missions (MU-1)	Projected upgrades to current Civilian Government Space systems/missions (CgU-1)	Projected upgrades to current Commercial Space systems/missions (CsU-1)
R&D Programs Supporting Baseline Missions	Planned R&D Programs supporting Baseline Missions (ore preparing for Excursion Options (MP-1)	Increased Projection of Civilian Government Space (CgP-1)	Minimal Changes in Commercial Space to reflect changes in government space (CsP-1)

$\boxed{}$ Components of the Baseline Requirements Model used by Space Operations

Figure 3 – NFS Space Mission and Requirements Model Details (including Excursions)

	Military Activities	Civilian Government	Commercial Space
BASELINE Missions, Upgrades and R&D Programs	Moderate Projection of Military Space Activities During the 1993-2023 Timeframe (MM-1, MU-1, MP-1)	Moderate Projection of Civil Government Space Activities During the 1993-2023 Timeframe (CgM-1, CgU-1, CgP-1)	Moderate Projection of Commercial Space Activities During the 1993-2023 Timeframe (CsM-1, CsU-1, CsP-1)
OPTION A Changes in Military Space Missions	Increased Projection of Military Space Actitivies (including MM-1, MU-1, MP-1, and MM-2)	Decreased Projection of Civilian Government Space Activities, and Adjustments to reflect DOD Changes	Minimal Changes in Commercial Space to reflect changes in government space
OPTION B: Changes in Civilian Missions, Upgrades and R&D Programs	Decreased Projection of Military Space Actitivies and Adjustments to reflect Civilian Government Changes	Increased Projection of Civilian Government Space (including CgM-1, CgU-1, CgP-1, and CgM-2, CgU-2, CgP-2)	Minimal Changes in Commercial Space to reflect changes in government space.
OPTION C: Changes in Commercial Space Missions	Minimal Changes in Military Space to reflect changes in Commercial Space	Moderate Changes in Civilian Government Space to reflect changes in Commercial Space	Increased Projection of Commercial Space Activities (including CsM-1, CsU-1, CsP-1, and CsM-2)

☐ Cases analyzed for the NFS

Viewed differently, groupings can themselves be grouped to create four top-level mission and requirements models:

- The Baseline
  The baseline Mission and Requirements Model; including the mission model (used by both Task Groups), the upgrades to those missions (used by Space R&D), and supporting R&D programs (used by Space R&D).

- Option A
  A Military Space Emphasis (used by Space R&D).

- Option B
  A Civilian Government Emphasis (used by Space R&D, with the development of an SSTO vehicle also used by Space Operations).

- Option C
  A Commercial Space Emphasis (used by Space R&D).

3.2 Baseline Missions

3.2.1 Commercial Space Baseline Missions (CsM-1)

The baseline requirements model for civilian commercial space activities includes four broad areas: launch systems, telecommunications, Earth observing and remote sensing, and in-space materials processing. Over the next three decades, the model projects that will be selected major new systems developments in the civilian commercial sector, focused on new telecommunications satellites. Demand for large vehicle launches of GEO telecommunications satellites is expected to remain relatively stable at 10 to 14 per year and the U.S. is expected to maintain a 40% share of the total space launch market relative to foreign launch providers. In particular, the baseline requirements model includes activities in the following areas:

1. **Launch Systems,** including (a) continuing operation of existing commercial expendable launch vehicle fleets through 2023, and (b) development of a new family of small payload low-cost ELVs after 1998;

2. **Telecommunications,** including (a) continuing operations of RF geostationary telecommunications satellite systems, with block upgrades through 2023, and (b) post 1995-1998, initiation of 1-2 LEO satellite constellations, with block upgrades through 2023;

3. **Earth Observing / Remote Sensing,** including modest commercial Earth remote sensing satellite operations following 2003; and,

4. **Materials Processing In Space,** including modest commercial materials processing operations following 2003.

3.2.1.1 Launch Systems

Current Fleet ELVs. The baseline includes continuing operation of existing commercial expendable launch vehicle fleets through 2023.

Immediate Timeframe (1993-1998). In the immediate future, commercial space ELV launches are projected to be almost exclusively in support of GEO telecommunications satellites. No major new ELV system developments are projected; there will be continuing upgrades of existing fleet systems.

Near-Term (1999-2003). In the 1999-2003 timeframe, commercial space ELV launches were projected to be largely in support of GEO telecommunications satellites. During the late 1990s, the model incorporates increasing launches of LEO constellations. In the timeframe, the baseline model assumed that foreign launch providers would participate in the launch of each major block changes (occurring every 16 years). Both the initial deployment and reconstitution phases of the system include small vehicle launches for replacement of failed or inoperative satellite nodes. In addition, a declining U.S. market share for small vehicle launches was assumed (80% for the 1990s, 65% for the 2000s, and 50% for the 2010s). No major new ELV system developments are projected; there will be continuing upgrades of existing fleet systems.

Intermediate-Term (2004-2013). In the intermediate timeframe, launch activities will continue at the level of the late 1990s for LEO and GEO constellations. No major new ELV system developments are projected; there will be continuing upgrades of existing fleet systems.

Far-Term (2014-2023). In the far-term, launch activities will continue at the level of the late 1990s for LEO and GEO constellations. No major new ELV system developments are projected; there will be continuing upgrades of existing fleet systems.

New Small ELV. In addition, the baseline includes development of a new family of small payload low-cost ELVs after 1998.

3.2.1.2 Telecommunications

GEO Satellites. Continuing operations of radio frequency (RF) geostationary Earth orbit (GEO) telecommunications satellite systems, with block upgrades through 2023, is included as a central element of the commercial space sector baseline requirements model. Cyclical replacement of current and projected systems cause periodic surges in the number of launches in the mid-1990s and immediately after the year 2000.

Immediate Timeframe (1993-1998). In the immediate future, no major new GEO system developments are projected; there will be continuing upgrades of existing telecommunication satellite systems.

Near-Term (1999-2003). In the near-term, No major new GEO system developments are projected; there will be continuing upgrades of existing telecommunication satellite systems.

Intermediate-Term (2004-2013). In the intermediate timeframe, No major new GEO system developments are projected; there will be continuing upgrades of existing telecommunication satellite systems.

Far-Term (2014-2023). In the far-term, no major new system developments are projected; there will be continuing upgrades of existing GEO telecommunication satellite systems.

LEO Constellations. In the mid-1990s timeframe, the baseline includes initiation of one 'small' low Earth orbit (LEO) telecommunications satellite constellation, a second 'large' constellation in the late 1990s, both with block upgrades through 2023.

Immediate Timeframe (1993-1998). In the immediate future, space-based telecommunications markets will continue to be dominated by GEO-based systems, with minimal entry by LEO constellations until the late 1990s. The baseline requirements model projects that one 'small' LEO telecommunications satellite system will become active. A representative systems was defined for purposes of analysis of the baseline model, consisting of 24 satellites with a four-year service life. This system is assumed to be improved overtime by periodic 'block' upgrades of satellites as they reach the end of their service life.

Near-Term (1999-2003). By the late 1990s, the baseline commercial space requirements model projects one big' LEO telecommunications satellite system will become active by the early years of the next decade. (Such 'big' LEO systems will provide global voice and high-speed data services on handheld receivers.) For the model, a representative system was devised consisting of 48 satellites with an intended service life of eight years. This system is assumed to be improved over time by periodic 'block' upgrades of satellites as they reach the end of their service life.

Intermediate-Term (2004-2013). In the baseline requirements model, no new LEO constellations are projected in the intermediate timeframe.

Far-Term (2014-2023). In the baseline requirements model, no new LEO constellations are projected in the far-term.

3.2.1.3 Earth Observing / Remote Sensing

The baseline forecast includes modest commercial Earth remote sensing satellite operations following 2003.

Immediate Timeframe (1993-1998). In the immediate future, the baseline includes no significant commercial space sector Earth observing or remote sensing activities.

Near-Term (1999-2003). In the near-term, demand for remote sensing payloads and products will depend partially on increased environmental concerns (with possible applications to forest management, pollution monitoring, resources planning, etc.), interest in ocean monitoring, and applications to urban planning and agriculture. This demand will be enhanced through improvements in key technologies (see the discussion in section 3.5).

Intermediate-Term (2004-2013). In the intermediate timeframe, the baseline forecast includes modest commercial Earth remote sensing satellite operations.

Far-Term (2014-2023). In the far-term, the baseline forecast includes modest commercial Earth remote sensing satellite operations.

3.2.1.4 Materials Processing In Space

The baseline forecast includes modest commercial materials processing operations following 2003.

Immediate Timeframe (1993-1998). In the immediate future, commercial materials processing activities will be very limited.

Near-Term (1999-2003). In the near-term, the baseline requirements model projects limited launches of commercial microgravity payloads.

Intermediate-Term (2004-2013). In the intermediate timeframe, the baseline projects continuation of the 1999-2003 level of activity.

Far-Term (2014-2023). In the far-term, the baseline projects continuation of the 1999-2003 level of activity.

3.2.2 Civilian Government Space Baseline (CgM-1)

The baseline requirements model for civilian government space activities also includes four broad areas: Mission to Planet Earth (MTPE) / Earth Observing, Space Science / Mission From Planet Earth (MFPE), Space Exploration and Development, and Space Technology. These areas parallel four of the five 'strategic enterprise' areas into which NASA's FY 1993-1994 strategic planning activities are organized. (The fifth NASA strategic enterprise area, Aeronautics Technology, is not germane to the space requirements model.) The components of the model within these areas are summarized below.

Over the next three decades, there will be several major new system developments after 2000-2005. The baseline requirements model includes specific mission/system/program activities in the following areas:

1. **Mission to Planet Earth / Earth Observing**, including (a) completion of the initial Earth Observing System (EOS) series; development & operation of second series involving small- to moderate- sized platforms through' 2023, and (b) NOAA operations of Weather Satellite System(s), with upgrades;

2. **Space Science/Mission From Planet Earth**, including (a) completion of the 'Great Observatories' followed by small & moderate-class Earth orbit science missions (e.g., AIM), and (b) changeover to small to moderate-class deep space probes for post-Cassini;

3. **Space Exploration and Development**, including (a) Space Shuttle operations (with upgrades) and the current expendable launch vehicles (with upgrades) through the 2023 timeframe, (b) development and launch of international redesigned space station with European, Japanese, Canadian and Russian elements and U.S. launch, with continuing operations through the 2023 timeframe, and (c) phased transition of the DSN to Ka-Band communications in 2003-2008; and,

4. **Space Technology**, including (a) selected NASA technology flight experiments (on Shuttle, Station, etc.), and (b) NASA R&D programs (including power, propulsion, small spacecraft, etc.).

3.2.2.1 Mission to Planet Earth / Earth Observing

Earth Observing System. The model includes the completion of the initial Earth Observing System (EOS) series during the next fifteen years. It also includes the development and operation of a second series involving small- to moderate- sized platforms through 2023.

Immediate Timeframe (1993-1998).[1] The Earth Observing System (EOS) is a multi-year, multiple platform program for studying the Earth's environmental interactions (including land, atmosphere, oceans & life). In the immediate future, two of the EOS spacecraft – each with diverse instruments – are planned for development and launch (circa 1998), including the EOS AM platform and the EOS COLOR platform. During the same period, a major data system will be developed to support the massive data sets that will be generated by the EOS program: the

[1] Note: In all 'mission' and 'upgrade' cases, the date(s) noted are the approximate dates for the launch and initial operational capability of the mission. For R&D program cases, the date(s) noted are intended to indicate the timeframe of implementation of the R&D. More detailed information regarding dates (e.g., for mission operations, or for system development activities) are provided in the references.

EOS Data and Information System (EOSDIS).

Near-Term (1999-2003). In the near-term, EOS will continue its development and operations as a multi-year, multi-platform program for studying the Earth's environmental interactions (including land, atmosphere, oceans & life). In the post-2001 timeframe, the EOS PM platform is planned to be launched into a polar orbit. Additional planned platforms include the EOS CHEM Platform (2002) and the EOS AERO platform (2003).

Intermediate-Term (2004-2013). In the intermediate timeframe, the initial series of EOS spacecraft will complete their missions. In this timeframe, the baseline requirements model projects that these spacecraft will not be repeated, but rather will be replaced by smaller spacecraft carrying similar (where possible miniaturized) instruments.

Far-Term (2014-2023). In the far-term, the intermediate term projection continues.

Operational Weather/Earth Observing Satellites. The baseline also includes NOAA operations of various civilian weather satellite system(s), with upgrades.

Immediate Timeframe (1993-1998). In the immediate future, several operational weather satellites are planned to be developed and launched, including NOAA-J (1994), NOAA-K (1996), NOAA-L (1997), several of the Geostationary Operational Environmental Satellites (GOES), including GOES-I, J and K, and LANDSAT-7 (1998). For example, the GOES spacecraft are ongoing elements in an operational system that will conduct continuous environmental observations, provide severe storm warnings, conduct search & rescue, and space environment monitoring. In addition, the NOAA E-M program of small, operational polar-orbiting satellites will provide various environmental observations and data for search and rescue operations.

Near-Term (1999-2003). In the near-term, additional NOAA operational weather satellites are projected to be developed and launched, including NOAA-M (1999), NOAA-N (2000 or 2001), GOES-K (1999) and GOES-L (2000).

Intermediate-Term (2004-2013). In the intermediate timeframe, additional NOAA operational weather satellites are projected to be developed and launched, including NOAA-O (2004), GOES-M (2005), GOES-N (2006), NOAA-P (2007), and NOAA-Q (2010). In the post-2010, a generic series of continuing Earth and weather observing systems is projected.

Far-Term (2014-2023). In the far-term, additional generic NOAA operational weather satellites are projected to be developed and launched, with launches approximately once per year.

Other Government Earth Observing Spacecraft. In addition to the EOS program and NOAA weather operational weather satellites, a variety of other Earth observing spacecraft are planned by the government.

Immediate Timeframe (1993-1998). In the immediate future, the baseline includes Earth Probes series, which are a series of small-to-moderate sized missions that will address highly focused problems in Earth Science. For example, one small spacecraft in the Earth Probes series, the Total Ozone Mapping Spectrometer (TOMS) will measure (in 1994) ozone concentrations in Earth's atmosphere using a variety of instruments. TOMS will be a precursor for later NOAA spacecraft instruments in the near- to mid- term. In addition, the Radar Satellite (RADARSAT) mission — a joint U.S.-Canadian program — is planned for a Delta ELV launch in 1994. RADARSAT will provide detailed information on sea ice, terrestrial ice sheets and diverse other targets (e.g., forestry and geology) using radar imagery.

Numerous Space Shuttle-based Earth observing activities are planned by NASA. For example, the Atmospheric Laboratory for Application and Science (ATLAS) is a Space Shuttle-based instrument payload for the study of the earth and its immediate space environs. Each flight in the series will last from 8-10 days. In 1994-1997, the ATLAS -3, -4 and -5 missions are planned for launch and operations. In addition, in 1994, the first flight of the Shuttle-Based Space Radar Laboratory (SRL) is planned. The SRL carriers a modified version of the Shuttle Imaging Radar (SIR-C) payload and the Measurement of Air Pollution from Satellites (MAPS) instruments and will provide radar images of the Earth surface as well as measuring global distribution of carbon dioxide in the troposphere. An additional flight of the SRL is planned in 1995 (SRL-2).

Also in the immediate timeframe, a 1994 mission,the Space Shuttle-based LIDAR In-Space Technology Experiment (LITE), will demonstrate the operation of active laser sensing for the study of the Earth's atmosphere. Later, in 1997, another in the series of joint US-European LAGEOS (Laser Geodynamics Satellite) missions is planned. The LAGEOS program provides information on the Earth by means of very precise satellite geodetic measurements provided by ground-based lasers and retroreflector cubes on two spacecraft.

Near-Term (1999-2003). In the near-term, the Earth Probes — a series of small-to-moderate sized missions that will address highly focused problems in Earth Science — will continue, including TRMM (Tropical Rainfall Monitoring Mission) to be launched in the post-1999 timeframe.

Intermediate-Term (2004-2013). In the intermediate timeframe, a continuing series of small- and moderate- scale Earth observing missions is projected.

Far-Term (2014-2023). In the far-term, a continuing series of small- and moderate-scale Earth observing missions is projected.

3.2.2.2 Space Science/Mission From Planet Earth

Astrophysics Missions. The baseline includes completion of the 'Great Observatories'. In the baseline, these will be followed by small- and moderate- class Earth orbit science missions.

Immediate Timeframe (1993-1998). In the immediate future, several smaller missions are planned, including the Explorer Program's X-Ray Timing Explorer (XTE). The XTE spacecraft (post-1995) will study temporal variability in compact space X-ray emitters. In the Small Explorer Program, diverse quick, and low-cost missions are planned. For example, the Submillimeter Wave Astronomy Satellite (SWAS) will be launched in post-1995. These missions will be competitively selected during the timeframe, however some current candidates being studied for launch before 1998 include:

- The Joint Ultraviolet Night Sky Observer (JUNO), which will perform a photometric and spectroscopic survey of the sky in the far UV. (JUNO would be collaboration between NASA and the Italian Space Agency).
- The Positron Electron Magnetic Spectrometer (POEMS), which will precisely measure the ratio of anti-electrons (positrons) to electrons among cosmic rays as a function of energy and time. (POEMS would be an international mission with participants from NASA and several European countries.)
- The Transitional Region and Coronal Explorer (TRACE), which will observe the Sun to study the connection between it's magnetic fields and plasma structures. TRACE would also be an international mission.

- The Wide-Field IR Explorer (WIRE), which will study the evolution of galaxies using cryogenically-cooled IR detector arrays.

(Two of these four may be launched in the 1997-1998 period.)

Similarly, the Explorer Program's Advanced Composition Explorer (ACE) spacecraft (planned for launch in 1997) will make particle observations, targeting energies ranging from 1 KeV per nucleon to 300 MeV per nucleon. Also in the immediate future, Space Shuttle payload bay hosted missions are planned, including the ASTRO-2 astrophysics instrument package, which is planned for a 10-day mission in the 1994 timeframe. Later in the period (1998), the Satellite Test of the Equivalence Principal (STEP) mission is planned to test theories regarding general relativity. Finally, during this timeframe, the Small Explorer (SMEX) program will be started, consisting of a series of very small, low-cost astrophysics spacecraft addressing very focused research questions. (Specific payloads will be identified over time through a competitive selection process.)

Near-Term (1999-2003). In the near-term, new small missions will be flown, including a series of University-Class Explorer (UNEX) missions (with the first flights in 1998 and 1999. These missions will continue (with flights in 2000, 2001, 2002, and 2003). An additional program of small missions, the Middle-class Explorer (MDEX) program will also begin (with flights in 2000, 2001, 2002 and 2003). For each of these programs, specific payloads will be determined through competitive Announcement of Opportunity (AO) solicitations. Later, one of the important moderate-scale missions that is planned is the Explorer Program's Far-Ultraviolet Spectroscopic Explorer (FUSE) spacecraft. Planned for launch in 2000-2001, FUSE will conduct high resolution spectroscopy at 800-1200 angstroms; moderate resolution to 100 angstroms, and do analysis of faint sources. Also, during this timeframe, the SMEX program will continue, consisting of a series of very small, low-cost astrophysics spacecraft addressing very focused research questions. (Specific payloads will be identified over time through a competitive selection process.)

One key near-term element of the baseline consists of the two spacecraft that comprise the Advanced X-Ray Astrophysics Facility (AXAF) mission AXAF is the X-ray component of the Great Observatories Program. The two spacecraft (targeted for launch in the late 1998 to 1999 timeframe) in the AXAF mission are: AXAF(i), which will do X-ray imaging and AXAF(s), which will do X-ray spectroscopy.

In the 2001 timeframe, a moderate-scale mission, the Submillimeter Intermediate Mission (SMIM) is projected. The SMIM will conduct the first spectral line sky survey in the 100-750 micron range (which is nearly inaccessible from the ground). Another moderate-scale mission (larger), the Gravity Probe-B (GP-B) mission is also planned for launch in the 2001 timeframe. GP-B will test our basic understanding of general relativity by making key dynamics experiments in the free-fall of Earth orbit.

At the end of the near-term, a key element of the baseline for astrophysics missions is the Space Infrared Telescope Facility (SIRTF). Planned for launch in the post-2003 timeframe, SIRTF (a.k.a., the Infrared Astronomical Mission, IRAM) is part of the 'Great Observatories' Series of astrophysics space missions. If implemented as currently planned, SIRTF will study the infrared portion of the spectrum with unprecedented resolution using a large (slightly less than 1 meter) aperture infrared telescope.

Intermediate-Term (2004-2013). In the intermediate timeframe, the several elements of the small-scale Explorer program activities will continue. For example, SMEX program will continue, consisting of a series of very small, low-cost astrophysics spacecraft addressing very focused research questions. UNEX missions and MDEX missions will also continue (with flights approximately annually throughout the period). For each of these Explorer programs, specific payloads will be determined through competitive Announcement of Opportunity (AO) solicitations. One key mission projected in this timeframe (2004) is the Astrometry Interferometry Mission (AIM).

Far-Term (2014-2023). In the far-term, the several elements of the Explorer program are projected to continue, consisting of a series of very small, low-cost astrophysics spacecraft addressing very focused research questions (including SMEX, UNEX and MDEX). Specific payloads will be identified over time through a competitive AO process.

Space Physics Missions. The baseline includes a number of small- to moderate- class space physics missions during the entire period of interest (1993-2023).

Immediate Timeframe (1993-1998). In the immediate future, for example, the Fast Auroral Snapshot Explorer (FAST) mission is planned for a 1994 Pegasus launch. A series of Earth-orbiting space physics missions are planned in the immediate timeframe, such as the Global GEOSPACE Science (GGS) Program (1993-1997 timeframe), which will involve observations of the solar wind to determine input properties (to the ionosphere). Multiple discrete spacecraft will be involved in the GGS program, including the GGS WIND Mission, and the GGS POLAR Mission. Also planned (for the post-1995 timeframe) is the Collaborative Solar-Terrestrial Research (COSTR) program, Solar & Heliospheric Observatory (SOHO) Mission that will characterize the structure of the solar interior and the dynamics of coronal plasma.

Near-Term (1999-2003). In the near-term, the two spacecraft of the Thermosphere-Ionosphere-Mesosphere Energetics and Dynamics (TIMED) program are planned (circa 1999). These will be small, miniaturized spacecraft. The Grand Tour Cluster (GTC) mission is planned for launch in this timeframe as well (e.g., circa 2000-2001). GTC will involve 4 individual spacecraft, flying in a tetrahedral configuration to provide three-dimensional characterization of magnetospheric plasma boundary regions and processes involved.

Intermediate-Term (2004-2013). In the intermediate timeframe, a continuing series of small- and moderate- scale space physics missions is projected. If costs can be reduced, one major program will be flown: the Solar Probe Mission (2010) which will send a thermally-protected spacecraft within less that 10 solar radii of the photosphere .

Far-Term (2014-2023). In the far-term, a continuing series of small- and moderate-scale space physics missions is projected.

Planetary Exploration Missions. The baseline model can be characterized as changing from flagship-class missions to to small- to moderate- class deep space probes for the post-Cassini era.

Immediate Timeframe (1993-1998). In the immediate future, the primary effort (already approved) is the Cassini Mission. Cassini will involve a single, large spacecraft, launched in the post-1997 timeframe and later placed in orbit around the planet Saturn, with a small probe (that is to be dropped to study Saturn's moon Titan). One of the key new missions planned (for a 1996 launch) is the first of the Discovery Program, the Mars Environmental Survey (MESUR)/Pathfinder mission. MESUR/Pathfinder will demonstrate lander, rover and science technologies on Mars in preparation for the MESUR Network. The MESUR/Network (planned to begin launches in 1998) will send (in a series of launches) one to two dozen small probes on the surface of Mars to study chemistry, climate and seismology over extended regions and periods of time. Also in the immediate future, the second Discovery Program mission, the Near Earth Asteroid Rendezvous (NEAR) is planned for a post-1996 launch.

Near-Term (1999-2003). In the near-term, the MESUR/Network (planned to begin launches in 1998) will continue its series of launches; ultimately landing one to two dozen small probes on the surface of Mars to study chemistry, climate and seismology over extended regions and periods of time. Also in this timeframe, the small Pluto Fast Fly-By (FFB) mission will be launched (1999 or 2000).

Intermediate-Term (2004-2013). In the intermediate timeframe, one of the key new components of the planetary science program will be the Towards Other Planetary Systems (TOPS) program. Beginning with ground-based elements in the mid-1990s, over a period of 1-2 decades, TOPS will search for and study planetary systems around other stars. In the 2003-2004 timeframe, the TOPS-1 mission will begin the space-based aspects of the study by searching systematically for Neptune/Uranus-class planets. 3-5 diverse concepts are under study. (Some of these are common to astrophysics mission concepts being examine for the same timeframe, such as AIM.)

Far-Term (2014-2023). In the far-term, the baseline model projects continuing small- and moderate- class deep space missions.

3.2.2.3 Space Exploration and Development

Access to Space. The baseline requirements model assumes continuation of existing systems for access to space throughout the period of interest.

Immediate Timeframe (1993-1998). In the immediate future, the baseline model assumes a continuation of Space Shuttle operations with approximately eight flights per year, with selected upgrades of specific systems. In the 1996-1997 timeframe, Space Shuttle flights for the assembly of the international Space Station will begin. In addition, the model projects the continuation of existing expendable launch vehicles (ELVs), including Delta, Atlas, Titan, and Pegasus vehicles where appropriate. (Specific payloads on these launches are discussed separately.)

Near-Term (1999-2003). In the near-term, the baseline model assumes a continuation of Space Shuttle operations with approximately eight flights per year, with selected upgrades of specific systems. Of these, approximately four per year are targeted to support completion of the assembly of the international Space Station in the 1999-2001 timeframe. Beginning in that timeframe, approximately 5-6 flights per year are targeted for Space Station logistics flights. In addition, the model projects the continuation of existing expendable launch vehicles (ELVs), including Delta, Atlas, Titan, and Pegasus vehicles where appropriate. (Specific payloads on these launches are discussed separately.)

Intermediate-Term (2004-2013). In the intermediate timeframe, the baseline model assumes a continuation of Space Shuttle operations with approximately eight flights per year, with selected upgrades of specific systems. Of these, approximately 5-6 are targeted for Space Station logistics flights. In addition, the model projects the continuation of existing expendable launch vehicles (ELVs), including Delta, Atlas, Titan, and Pegasus vehicles where appropriate. (Specific payloads on these launches are discussed separately.)

Far-Term (2014-2023). In the far-term, the baseline model assumes a continuation of Space Shuttle operations with approximately eight flights per year, with selected upgrades of specific systems. As appropriate, flights will provide logistics for the international Space Station. In addition, the model projects the continuation of existing expendable launch vehicles (ELVs), including Delta, Atlas, Titan, and Pegasus vehicles where appropriate. (Specific payloads on these launches are discussed separately.)

Space Station. The model includes development and launch of international redesigned space station with European, Japanese, Canadian and Russian elements and U.S. launch, with continuing operations through the 2023 timeframe.

Immediate Timeframe (1993-1998). As presently configured, the Redesigned Space Station will be implemented in LEO during a series of phases, with increasing levels of capability. In the post-1997 timeframe, phase 1 of the redesigned station will be implemented. It will provide a base of services, including power, thermal and GN&C.

Near-Term (1999-2003). In the near-term, the development of the international Space Station will continue in LEO with the integration of selected international hardware and beginning of logistic resupply Space Shuttle flights to support the developing in-space infrastructure.

Intermediate-Term (2004-2013). In the intermediate timeframe, the fully operational international Space Station will continue operations, with regular resupply by the Space Shuttle.

Far-Term (2014-2023). In the far-term, the fully operational international Space Station will continue operations, with regular resupply by the Space Shuttle.

Mission Operations and Telecommunications. The model also includes continuing development of mission operations and telecommunications systems, including a phased transition of the NASA Deep Space Network (DSN) to Ka-Band communications in 2003-2008.

Immediate Timeframe (1993-1998). In the immediate future, continued operations, with some continuing engineering development and upgrades of the NASA Deep Space Network (DSN) are planned. In addition, in the 1995-1996 timeframe, the launch of additional spacecraft in the Tracking and Data Relay Satellite System (TDRSS) is planned (TDRS-G).

Near-Term (1999-2003). In the near-term, additional launches of TDRSS spacecraft are planned, including launches to GEO in 1998 (TDRS-F8), 1999 (TDRS-F9), 2000 (TDRS-F10). At present, the beginning of a new, more capable TDRSS, TDRSS-II is projected in the baseline requirements model is projected in this timeframe. This includes the first spacecraft in the new system, TDRS II-F1, in 2001, followed by the second and third spacecraft, in 2002 (TDRS II-F2) and 2003 (TDRS II-F3).

Intermediate-Term (2004-2013). In the intermediate timeframe, the transition of the NASA DSN to Ka-Band operations is projected to increase data rates or reduce spacecraft communications systems size/weight and costs. In the same period, additional spacecraft in the TDRS II series are projected, including launches in 2004 (TDRS II-F4), 2006 (TDRS II-F5), and 2008 (TDRS II-F6). Following 2010, the regular launch of highly capable telecommunications satellites to meet government high-bandwidth requirements (successors to the TDRSS) to GEO operational stations is assumed as a part of the baseline model.

Far-Term (2014-2023). In the far-term, continuing operations of the DSN in S-Band, X-Band, and Ka-Band is assumed in the baseline. In addition, the regular launch (once every 1-2 years) of highly capable telecommunications satellites to meet government high-bandwidth requirements (successors to the TDRSS) to GEO operational stations is assumed as a part of the baseline model.

3.2.3 Military Baseline Missions (MM-1)[2] (Current Unclassified Military Systems)

These are the systems currently being worked by the DoD, additionally the major contractors in support of these systems are identified to add a cross-link to civilian commercial space requirements (CsM-1).

3.2.3.1 Communication and Navigation

Air Force Satellite Communications (AFSATCOM). The AFSATCOM represents one of the three pillars of the Military Satellite Communication (MILSATCOM) architecture identified by the Defense Information Systems Agency (DISA). The MILSATCOM Joint Program Office, located at Los Angeles Air Force Base, manages the acquisition of the MILSTAR system, Defense Satellite Communications System (DSCS), and the AFSATCOM (Mission 12). (Contractors: Lockheed, TRW, Hughes, and General Electric.) Key dates/timeframes for AFSATCOM include:

Immediate Timeframe (1993-1998). In the immediate future, AFSATCOM which is already an operational system, will continue in operation.

Near-Term (1999-2003). In the near-term, the excursion includes continuing operations for AFSATCOM (with end of operations in the 2004 timeframe).

Defense Satellite Communications System (DSCS) III. DSCS satellites provide worldwide secure voice and data transmission. They are used for high-priority communications, such as communicating war-time data between defense officials and battlefield commanders. The system also transmits data on space operations and early warning to various systems and users. Phase II and Phase III satellites are currently in geosynchronous orbit (Airman 56). (Contractors: TRW & General Electric, Aerojet, IBM.; Dimensions: Phase II -- cylindrical body is 9 ft. in diameter and 9 ft. long. Phase III -- rectangular body, 6 ft. x 6 ft x 7 ft. Weight: Phase II -- 1,350 lbs.; Phase III -- 2,500 lbs.) Key dates/timeframes for DSCS III include:

Immediate Timeframe (1993-1998). In the immediate future, DSCS III which is already an operational system, will continue in operation.

Near-Term (1999-2003). In the near-term, the excursion includes continuing operations for DSCS III.

Intermediate-Term (2004-2013). In the intermediate timeframe, the excursion includes continuing operations for DSCS III (with end of operations in the 2010 timeframe).

MILSTAR I. The Military Strategic and Tactical Relay System, or MILSTAR, is the world's most advanced satellite communications network. The system features jam-resistant ultra high, extremely high and super high frequency communication links that promise commanders and national leaders a continuous secure flow of information worldwide (Powell 10). (Contractors: Lockheed, TRW, Hughes, and General Electric.) Key dates/timeframes for MILSTAR include:

Immediate Timeframe (1993-1998). In the immediate future, MILSTAR which is already an operational system, will continue in operation.

Near-Term (1999-2003). In the near-term, the excursion includes continuing operations for MILSTAR (with end of operations in the 2002 timeframe).

[2] The key sources for material provided in Sections 3 and 4 on military missions, upgrades and supporting R&D programs derive from the Joint Services Program Plan (JSPP) and appropriate R&D roadmaps.

NAVSTAR Global Positioning System (GPS) II/IIA. The NAVSTAR GPS is a configuration of orbiting satellites that provide navigation data to military and civilians around the globe. When it becomes fully operational in 1994, 24 satellites -- orbiting the Earth every 24 hours -- will provide accurate around-the-clock navigation services, including latitude, longitude and altitude information. Receivers are located in aircraft, ships and ground vehicles. Data is extremely accurate, enabling users to determine time within a millionth of a second, speed within a fraction of a mile per hour, and location within a few feet. Functions such as mapping, aerial refueling and rendezvous, geodetic surveys and search and rescue also benefit from the system (Airman 56). (Contractors: Rockwell International, General Electric, IBM, Trimble, Megallan, et al.; Dimensions: width 5 ft, length 17 ft. 6 in. including solar array. Weight: 1,860 lbs. in orbit.) Key dates/timeframes for GPS include:

Immediate Timeframe (1993-1998). In the immediate future, GPS II/IIA which is already an operational system, will continue in operation.

Near-Term (1999-2003). In the near-term, the excursion includes continuing operations for GPS II/IIA (with end of operations in the 2001 timeframe).

Polar Communication Satellite. The Polar Communications Satellite is notional proposed system option to improve communications operations. Additional information TBD. (Contractors: TBD) Key dates/timeframes for Polar Communications Satellite include:

Immediate Timeframe (1993-1998). In the immediate future (1995) the technology freeze date for the Polar Communications Satellite will occur.

Near-Term (1999-2003). In the near-term (post-2000), the excursion includes initial operations for Polar Communications Satellite (with end of operations TBD).

Ultra-High Frequency (UHF) Follow-On (UFO). The UHF satellite represents one of the three pillars of MILSATCOM architecture identified by DISA. UHF band turns out to be the frequency band of choice in serving such a large mobile, and geographically dispersed user community. The unification of DoD communication satellites led to the MILSTAR program, and subsequently the initiation to UFO. The Joint Chiefs of Staff (JCS) requirements for the UFO capability are defined in JCS Document, MJCS 48-87 of 31 March 1987, basically as follows: (1) The satellites are to be compatible with existing UHF SATCOM terminals; (2) The satellites are to have a jam-protected FLTBDCST capability; (3) The satellites are to be capable of autonomous operations in the case of failure of ground stations; and, (4) The satellites are to be capable of being launched either by expendable launch vehicle or by the Shuttle. F3 is scheduled for launch in April 1994, with two per year F9 should go up August 1996 (Diederich 1-5) (Contractors: General Motors (Hughes), McDonnell Douglas.) Key dates/timeframes for UFO include:

Immediate Timeframe (1993-1998). In the immediate future, initial operations for the UFO will occur (circa 1998), with continuing operations through post-2009.

3.2.3.2 Surveillance / Earth & Weather Observing

Defense Meteorological Satellite Program (DMSP). Development, deployment and operations of systems (e.g. Block VI). DMSP vehicles have been collecting weather data, including atmospheric moisture and temperature levels, for U.S. military operations for more than two decades. Two Block 5D-2 satellites orbit the Earth, taking visual and infrared imagery of cloud cover. Military weather forecasters use the data to detect developing weather patterns around the globe and help identify, locate and determine the severity of thunderstorms, hurricanes and typhoons. The systems also can locate and determine the intensity of electromagnetic phenomena that can in interfere with radar operations and long-range communications. Systems orbit about 500 miles above the Earth and can scan an area 1,800 miles wide. Each system covers the Earth about every 12 hours (Airman 56 & Mission 11). (Contractors: General Electric, Westinghouse, Hughes, Aerojet, Harris, Lockheed; Dimensions: height, 11 ft.,6 in.; width, 4 ft, 9 in,; length, 19 ft. 3 in. Weight: 1,750 lbs.) Key dates/timeframes for DMSP include:

Immediate Timeframe (1993-1998). In the immediate future, the initial operations for DMSP will occur (with end of operations in the TBD timeframe).

Defense Support Program (DSP). The Defense Support Program detects missile launches, space launches and nuclear detonations. It feeds warning data to NORAD and U.S. Space Command early warning centers at Cheyenne Mountain, Colorado. The system has provided uninterrupted early warning capability since it was first launched in the early '70s. It detected Iraqi Scud missile launches during the Persian Gulf war, provided warning to civilian populations and coalition forces in Israel and Saudi Arabia. It orbits about 22,000 miles above Earth and uses infrared sensors to recognize heat from missile and booster plumes against Earth's background (Airman 56). (Contractors: TRW, Aerojet, IBM.; Dimensions: diameter 22 ft; height, 32 ft, 8 in. with solar paddles deployed. Weight: about 5,000 lbs.) Key dates/timeframes for DSP include:

Immediate Timeframe (1993-1998). In the immediate future, the DSP technology freeze date will occur (1997).

Near-Term (1999-2003). In the near-term, the DSP development will be conducted.

Intermediate-Term (2004-2013). In the intermediate timeframe, the initial operations for DSP will take place (with end of operations in the post-2015 timeframe).

Follow-on Early Warning System (FEWS). The FEWS will provide the first warning of ballistic missile attack against the U.S. or it's allies. It is the next generation space surveillance system being developed to replace DSP. Using recent technology developed as part of the Strategic Defense Initiative, FEWS will detect, track, count, and identify ballistic missile launches worldwide. In addition to the global mission, FEWS will address the growing multi-theater threats caused by proliferation of ballistic missiles world-wide (Mission 13). (Contractors: Lockheed/Hughes and TRW/Grumman.) Key dates/timeframes for FEWS include:

Immediate Timeframe (1993-1998). In the immediate future, the FEWS technology freeze date will occur (1995).

Near-Term (1999-2003). In the near-term, the FEWS development will be conducted.

Intermediate-Term (2004-2013). In the intermediate timeframe, the initial operations for FEWS will take place (with end of operations in the post-2015 timeframe).

GEOSAT Follow-On (GFO). GFO is an operational series of radar altimeter satellites that will maintain continuous ocean observation from GEOSAT Exact Repeat Orbit. The satellites will include all the capabilities necessary for the precise measurement of both mesoscale and basin-scale oceanography. The follow-on spacecraft will add a water vapor radiometer and GPS receiver to the basic GEOSAT capability. At least one satellite is planned throughout a 10-year period, starting in 1996 (Finkelstein 1-3). (Contractors: Ball Aerospace Corporation, E-Systems Corporation, AIL, Lockheed Missile and Space Co.; Dimensions: 3 meters long. Weight: 300 kg spacecraft)

LANDSAT VII. LANDSAT is an earth observing, multispectral (six spectral bands ranging from visible to infrared) optical satellite system with 30 meter resolution. Key dates/timeframes for LANDSAT VII include:

Immediate Timeframe (1993-1998). In the immediate future, the initial operations of an accelerated LANDSAT VI may occur (circa 1999).

Near-Term (1999-2003). In the near-term, the LANDSAT VII initial operations will take place (with end of operations in the TBD timeframe).

3.2.3.3 Missile Offense and Launch Systems

Air Force Satellite Control Network, Eastern & Western Space Launch Ranges. The Satellite Control and Data Handling Program Office is responsible for management of programs to design, develop, acquire, and integrate systems of the Air Force Satellite Control Network and Eastern & Western Space Launch Ranges. The systems provide tracking, orbital analysis, receiving and processing of telemetry data, and commanding of satellites, launch vehicles, and space experiments (Mission 14). (Contractors: IBM, Loral, Applied Technology Associates, Space Applications Corporation.)

D-5 (Trident). Detailed information was not available on this program at the time of writing.

Guidance Replacement Program (GRP). The Silo-Based ICBM Development Support Organization is responsible for all development activities related to U.S. silo-based ICBMs, including the GRP for the Minuteman III guidance system (Mission 17). (Contractors: Thiokol, Rockwell, Aerojet, Hercules, Loral, Martin Marietta.)

Launch Systems Program (Atlas and Delta). The Launch Systems Program acquires the Atlas and Delta medium launch vehicles used primarily for communications and navigation satellites and scientific payloads. The Atlas II is a medium launch vehicle used primarily for communications satellites such as the DSCS. The Delta II, also a medium launch vehicle, is currently used for NAVSTAR GPS and Air Force and NASA scientific payloads (Mission 16). (Contractors: General Dynamics, McDonnell Douglas, Boeing Aerospace.)

Minuteman life extension program. The Minuteman missile has been on strategic alert since 1962 and has undergone several modifications since initial deployment. The Minuteman III has three solid-propellant stages and a maneuverable deployment vehicle. The missile can carry three independently targetable reentry vehicles. The missile is hot-launched, meaning its first stage ignition is in its silo (SMC LAAFB 15). See GRP and REACT (Dimensions: 60 feet long; Weight: 78,000 lbs at liftoff.)

Rapid Execution and Combat Targeting (REACT). The Silo-Based ICBM Development Support Organization is responsible for all development activities related to U.S. silo-based ICBMs, including the development and installation of the REACT upgrades to ICBM launch control facilities (Mission 17). (Contractors: Thiokol, Rockwell, Aerojet, Hercules, Loral, Martin Marietta.)

Titan IV. The latest generation in a long history of successful boosters, the Titan IV is the Air Force's heavy-lift vehicle for shuttle-class payloads, and is launched from both coasts. One configuration of the Titan IV uses the Centaur, the most powerful upper stage in the U.S. inventory. The Titan Program Office also manages the conversion of Titan II ICBMs into expendable space launch vehicles (Mission 15). (Contractors: Martin Marietta, General Dynamics.)

3.2.3.4 Classified Programs

In addition, the baseline requirements model includes appropriate classified mission and programs.

3.3 U.S. Launch Capability to Support the Baseline Mission Model

Section 2.3 provides a discussion of U.S. space launch capability needs and plans to support the baseline mission model. In addition, Appendix D provides detailed projections of launch requirements and their accommodation.

3.4 Baseline Mission Upgrades (Space R&D)

3.4.1 Commercial Space Upgrades (CsU-1)

3.4.1.1 Launch Systems

Current Fleet ELVs. The baseline includes continuing operation of existing commercial expendable launch vehicle fleets through 2023.

Immediate Timeframe (1993-1998). In the immediate future, commercial space ELV launches were projected to be almost exclusively in support of GEO telecommunications satellites; no specific upgrades are projected.

Near-Term (1999-2003). In the near-term, substantial upgrades of the technologies in existing ELV fleet systems are projected. During the late 1990s, the model incorporated increasing launches of LEO constellations. In the timeframe, the baseline model assumed that foreign launch providers would participate in the launch of each major block changes (occurring every 16 years). Both the initial deployment and reconstitution phases of the system include small vehicle launches for replacement of failed or inoperative satellite nodes. In addition, a declining U.S. market share for small vehicle launches was assumed (80% for the 1990s, 65% for the 2000s, and 50% for the 2010s).

Intermediate-Term (2004-2013). In the intermediate timeframe, substantial upgrades of the technologies in existing ELV fleet systems are projected.

Far-Term (2014-2023). In the far-term, substantial upgrades of the technologies in existing ELV fleet systems are projected.

New Small ELV. In addition, the baseline includes development of a new family of small payload low-cost ELVs after 1998.

3.4.1.2 Telecommunications

GEO Satellites. Continuing operations of radio frequency (RF) geostationary Earth orbit (GEO) telecommunications satellite systems, with block upgrades through 2023, is a central element of the baseline requirements model. Cyclical replacement of current and projected systems cause periodic surges in the number of launches in the mid-1990s and immediately after the year 2000.

Immediate Timeframe (1993-1998). In the immediate future, a number of block upgrades of GEO telecommunications satellites will continued, as required.

Near-Term (1999-2003). In the near-term, a number of block upgrades of GEO telecommunications satellites will continued, as required.

Intermediate-Term (2004-2013). In the intermediate timeframe, a number of block upgrades of GEO telecommunications satellites will continued, as required.

Far-Term (2014-2023). In the far-term, a number of block upgrades of GEO telecommunications satellites will continued, as required.

LEO Constellations. In the mid-1990s timeframe, the baseline includes initiation of one 'small' LEO telecommunications satellite constellation, with subsequent block upgrades through 2023.

Immediate Timeframe (1993-1998). In the immediate future, space-based telecommunications markets will continue to be dominated by GEO-based systems, with minimal entry by LEO constellations until the late 1990s.

Near-Term (1999-2003). By the late 1990s of the next decade, the baseline commercial space requirements model projects that 1-2 LEO telecommunications satellite system will become active; no upgrades will be required in the late 1990s or early years of the next century.

Intermediate-Term (2004-2013). In the baseline requirements model, both the 'big' and 'small' LEO telecommunications satellite constellations are projected to be improved over time with block upgrades in the intermediate timeframe.

Far-Term (2014-2023). In the far-term, both the 'big' and 'small' LEO telecommunications satellite constellations are projected to be improved over time with block upgrades incorporating new technologies.

3.4.1.3 Earth Observing / Remote Sensing

The baseline forecast includes modest commercial Earth remote sensing satellite operations following 2003.

Immediate Timeframe (1993-1998). In the immediate future, there are no projected commercial Earth observing or remote sensing activities or upgrades.

Near-Term (1999-2003). In the near-term, there are no projected commercial Earth observing or remote sensing activities or upgrades.

Intermediate-Term (2004-2013). In the intermediate timeframe, limited upgrade activities for commercial remote sensing and Earth observing activities are projected in the baseline model.

Far-Term (2014-2023). In the far-term, limited upgrade activities for commercial remote sensing and Earth observing activities are projected in the baseline model.

3.4.1.4 Materials Processing In Space

The baseline forecast includes modest commercial materials processing operations following 2003.

Immediate Timeframe (1993-1998). In the immediate future, there are no projected commercial materials processing activities or upgrades.

Near-Term (1999-2003). In the near-term, there are no projected commercial materials processing upgrades.

Intermediate-Term (2004-2013). Following the near-term, limited upgrade activities for commercial in-space materials processing activities are projected in the baseline model.

Far-Term (2014-2023). In the far-term, limited upgrade activities for commercial in-space materials processing activities are projected in the baseline model.

3.4.2 Civilian Government Space Upgrades (CgU-1)

Because of the exploratory nature of most civilian government space activities, upgrades of capability are (in most cases) listed as a part of the baseline mission descriptions provided above in Section 3.2. Some specific exceptions are noted below.

Space Science/Mission From Planet Earth. The Hubble Space Telescope (HST) is part of the 'Great Observatories' Series of Astrophysics space missions. Due to an aberration in the primary mirror of the telescope, a series of repair and maintenance mission are planned for the HST in 1993. In addition, further instrument replacement missions are planned during the course of the telescope's projected 15-year mission lifetime.

3.4.3 Military Upgrades (MU-1)
Upgrades to Current Unclassified Systems

This part of the baseline includes, but is limited to, the planned initial upgrades of existing current systems. These systems are sorted by mission area and title.

3.4.3.1 Communication and Navigation

Defense Satellite Communications System (DSCS). This satellite provides super high frequency communications primarily for high capacity fixed users. The MILSATCOM Joint Program Office manages the acquisition of DSCS (Mission 12). (Contractors: Lockheed, TRW, Hughes, and General Electric.) Some key technical areas associated with this upgrade include:

- Communication Systems
- Satellite Control System Technology
- Energy Storage
- Environment (hostile, natural, passive)
- Space Electronics and Software
- Structures
- Techniques Active

MILSTAR II. See MILSTAR in Section 3.2. Some key technical areas associated with this upgrade include:

- Communication Systems
- MILSATCOM Technology
- Navigation System Technology
- Satellite Control / System Technology

- Data Processors
- Energy Storage
- Environment (hostile, natural, passive)
- Heat Transfer / Dissipation
- Photovoltaics
- Space Electronics and Software
- Structures
- Techniques Active

3.4.3.2 Surveillance / Earth & Weather Observing

Defense Meteorological Satellite Program (DMSP) VI. See DMSP in Section 3.2. Some key technical areas associated with this upgrade include:

- Energy Storage
- Environments (hostile, natural, passive)
- Photovoltaics
- Space Electronics and Software
- Structures
- Techniques Active

3.4.3.3 Missile Offense and Launch Systems

Advanced Missile Systems (ICBM systems and subsystems) The Advanced Missile Systems Program Office conducts technology demonstrations and advanced development of ICBM systems and subsystems. The program office translates operational requirements into demonstrated concepts and technology options. It also has ongoing work in reentry systems, missile guidance and electronics, and strategic missile technologies (Mission 15). (Contractors: General Electric, Litton, et al.) Some key technical areas associated with this upgrade include:

- Energy Storage
- Environments (hostile, natural, passive)
- Photovoltaics
- Space Electronics and Software
- Space Launch Propulsion
- Structures
- Techniques Active

3.5 Baseline Mission-Supporting R&D Programs (Space R&D)

3.5.1 Civilian Commercial Space Research and Development Programs (CsP-1)

The following paragraphs provide a summary description of selected R&D areas that will be significant in the commercial space baseline.

Immediate Timeframe (1993-1998). In the immediate future, there will be several new system developments, but these will draw predominantly on existing technologies.

Near-Term (1999-2003). In the near-term, new battery technologies, in particular NiH2 batteries, will become dominant in communications satellite applications. In the same approximate timeframe, phased array (steered) antenna and hopping spot beam coverage will become commonplace in flexibly meeting changes in traffic demand.

Also in the near-term, demand for commercial microgravity payloads will be affected by greater usage of reentry vehicles for microgravity experimentation, particular in the areas of pharmaceutical research and on-orbit materials processing and/or manufacturing.

Intermediate-Term (2004-2013). In the intermediate timeframe, various new technologies are expected to be incorporated into both 'small' and 'big' LEO telecommunications systems, including (for the first replacement phase, circa 2006):

- phased array/multiple beam antennas for service flexibility
- higher performance filters, multiplexers and frequency-stabilized oscillators for improved transponder performance
- attitude determination control (ADC) subsystems for narrower satellite pointing beams

In the same period, a variety of key technology developments are projected that would substantially support the development of commercial space remote sensing and Earth observing activities. These include:

- significantly higher resolution capabilities for commercial remote sensing
- synthetic aperture radar (SAR) capability for small, commercial remote sensing spacecraft
- the usage of composite materials structures (allowing lighter weight bus structures, components, etc.
- onboard data storage

Far-Term (2014-2023). In the far-term, additional 'big' and 'small' LEO system technology improvements are projected to include:

- greater usage of advanced composite materials such as Kevlar or carbon-carbon-based materials (circa 2014)
- on-board process for baseband signal regeneration (circa 2014)
- spacecraft onboard health monitoring systems (after 2012)

3.5.2 Civilian Government Space R&D Programs (CgP-1)

In the NFS requirements model, the civilian government space R&D programs section includes both (a) ground-based technology development and (b) in-space research activities (either at the basic science level, such as life sciences or microgravity research) or at the technology validation level (e.g., in-space technology experiments).

3.5.2.1 Technology Research and Development

In general, civilian government technology R&D activities in the baseline mode are focused on (a) meeting the needs of government missions (in selected space technology areas, cited below), (b) meeting the needs of the aerospace industry and the commercial space sector (largely through cooperative programs), and (c) transferring aerospace technologies into the non-aerospace sector.

Immediate Timeframe (1993-1998). In the immediate future, NASA's Office of Advanced Concepts and Technology (OACT) will conduct a continuing program of advanced technology programs for future government and commercial space missions, including miniaturized spacecraft, operations, launch vehicles (piloted or unpiloted), and Space Station systems and operations. In the same timeframe, OACT will oversee an increasing program of industry-led advanced technology projects that meet the needs of future government and commercial space activities with strong dual-use potential.

Selected key R&D areas planned for investment include:

- Spacecraft power systems to increase performance and reduce cost (including solar power, chemical energy storage, thermal-to-electric conversion, and power & thermal management)
- Space environmental effects and interactions
- Low-cost advanced spacecraft structures (e.g., structural concepts and dynamics) and materials (e.g., composites)
- High performance, cryogenic Earth-to-orbit high-thrust propulsion
- Advanced in-space propulsion technologies (including both cryogenic fluid management and low thrust engines, such as electric propulsion)
- Information, data management and controls technologies (including on-board avionics, and telecommunications such as digital, RF, and optical communications for both space and ground segment applications)
- Sensors in diverse areas, such as in situ sensors (e.g., for trace gas detection) and for remote sensing (e.g., arrays, direct detectors, etc.), and sensors supporting technologies (such as cryogenic coolers)
- Telescope optics and optical systems
- Robotics and artificial intelligence applications for on-the-ground and in-space systems and for planetary surface missions (e.g., miniaturized mobile surface robots - 'rovers')
- Microprecision controls-structures-interaction (CSI) technologies (e.g., for interferometer applications)

Near-Term (1999-2003). In the near-term, the technology areas under development in the immediate (1993-1998) timeframe will continue.

Intermediate-Term (2004-2013). In the intermediate timeframe, the technology areas under development in the immediate (1993-1998) timeframe will continue.

Far-Term (2014-2023). In the far-term, the technology areas under development in the immediate (1993-1998) timeframe will continue.

3.5.2.2 Technology Development Flight Experiments

The baseline includes selected NASA technology development flight experiments (on Shuttle, Station, etc.)

Immediate Timeframe (1993-1998). In the immediate future, the OACT In-Space Technology Experiments Program (IN-STEP) will develop and fly a series of technology development and demonstration flight experiments. These experiments, which are competitively selected, may be either Shuttle-based or free flying. Some of the technical areas in which technology flight experiments are being developed include:

- Structural and system dynamics and controls

- Fluid behavior and management in microgravity
- Innovative structural concepts (e.g., inflatable antenna structures)
- Space-borne atomic clocks (e.g., hydrogen masers)
- Various other technical areas

Near-Term (1999-2003). In the near-term, small-scale technology flight experiments are projected to continue.

Intermediate-Term (2004-2013). In the intermediate timeframe, small-scale technology flight experiments are projected to continue.

Far-Term (2014-2023). In the far-term, small-scale technology flight experiments are projected to continue.

3.5.2.3 Microgravity Research Missions

Selected specific microgravity research programs are described in the paragraphs that follow.

Immediate Timeframe (1993-1998). In the baseline, a number of microgravity materials processing flight missions are included in the model for the immediate future. The major immediate mission activity will be a number of flights (in 1994-1995) of the Space Shuttle-based SpaceHab microgravity research laboratory.

In addition, planned for 1994, the second flight of the International Microgravity Laboratory (IML-2) will provide opportunities for a variety of microgravity research efforts. IML, an application of the Spacelab, is a pressurized laboratory in the Shuttle Bay, with experiments focused on material and life sciences. Also planned for 1994, the second flight of the U.S. Microgravity Payload (USMP-2) will carry four major experimental facilities in the Space Shuttle payload bay (outside the life support environment of the Shuttle middeck). USMP addresses basic research questions for materials processing technologies and microgravity environments, including advanced zero gravity furnace technologies, the properties of materials during phase transitions, and other experiments.

In 1995, the second flight of the U.S. Microgravity Laboratory (USML-2) will focus on materials process technologies for microgravity. USML, an application of the Spacelab pressurized laboratory in the Shuttle Bay, includes opportunities for research in crystal growth (furnaces), drop physics, protein crystal growth, and other experiments (e.g., bioprocessing).

Near-Term (1999-2003). In the later half of the 'near-term' timeframe,the Centrifuge Facility program will place (post-2000) a suite of equipments on the international/redesigned Space Station to conduct studies of the biological effects of variable gravity in space. Some of the other areas of microgravity research that will be done on the Station include:

- Biotechnology
- Combustion Research
- Fluid Physics
- Materials Science

Intermediate-Term (2004-2013). In the intermediate timeframe, research will continue on the international Space Station. If it has not already been launched, then in the early years of the intermediate period, the U.S. laboratory module will be launched and being operations. One of the key elements of the U.S. laboratory will be the Space Station Furnace Facility (SSFF), which will provide various services — cooling, purge gas, power conditioning and control, etc. — for a series of furnace modules in the laboratory.

Far-Term (2014-2023). In the far-term, continuing basic research at the international Space Station is projected.

3.5.3 Military Research and Development Programs (MP-1) Military Technology Development and Flight Experiment Programs

3.5.3.1 Technology Development

The DoD requirements baseline is limited to the technology areas found within the taxonomy of JDL. These are R&D technology push-programs that will not result directly into a current or planned space system. This list represents only the non-classified programs; nevertheless, all space programs are accounted for in the space operations model and launch schedule.

Astronics. (The science and integration technology of radiation hardened electronics, sensors, and communication devices including related software for the astronautical environment) Currently this is an informal liaison coordination activity with other JDL technology panels for a number of technology areas not within the domain of the Space Vehicles Technology Panel, but of vital importance to the Panel's applications and objectives. These areas include:

- Space (radiation hardened) Sensors
- Space Communications
- Space Electronics / radiation hardened Electronics
- Spacecraft Software

Flight Experiments. These experiments are use to for technology validation in the space environment. Technology validation may consist of data collection to prove that an analytical prediction is in fact correct, or that a component or subsystem that works in the laboratory also works in space. Flight Experiment work is divided into two efforts:

- Spacecraft Software
- Experiment Coordination
- Flight Opportunities (See Flight Experiments below).

Guidance, Navigation, and Control (GN&C). GN&C addresses satellite navigation and attitude determination and control technologies. Ballistic/interceptor missile technology is included in GN&C when space related.

Attitude. This technology is concerned with determining the orientation of a spacecraft or missile to a coordinated frame. It includes determining the orientation of the vehicle, guiding it to a new orientation, and controlling it to a desired orientation with required accuracy.

Navigation. To better determine the position of a spacecraft or missile with respect to a coordinate frame and to guide it to a new position.

Power (for space systems). This technology addresses the development of on-board power systems for space vehicles. This includes:

- Energy Storage
- Photovoltaics
- Power Management and Distribution
- Space Nuclear Power (Including a thermionic evaluation of Topaz II)

Propulsion. This area includes all aspects of propulsion technology as it relates to space launch propulsion, orbit transfer and maneuvering propulsion.

- High Energy Density Materials (HEDM)
- Orbit Transfer and Maneuvering Propulsion
- Space Launch Propulsion
- Thermophysics

Structures (for spacecraft and payloads). This technology addressees application of advanced materials to DoD spacecraft and launch vehicles, but does not include basic research that goes into the development of advanced materials for multiple, generic use. Areas of focus are:

- Advanced Materials Applications
- Construction Techniques
- Structural Control and Damping

Survivability. This covers both the technology associated with the weapon and natural environment threats as well as the technology for developing active and passive hardening techniques (countermeasures) against those threats.

- Environment
- Techniques

Thermal Management and Control. This program focuses on cryogenic and heat transfer and dissipation development programs.

- Cryocooler Technologies
- Heat Transfer / Dissipation Technologies

3.5.3.2 Flight Experiment Programs

Below are listed the details of the most important flight experiments required by the Department of Defense over the next five years. This list does not include all planned flight experiments, but does have all planned future (beyond 1993) flights of interest to this study.

Advanced Resin Matrix Composite Structures Technology for Space Applications. This program will demonstrate the ability to consistently produce advanced resin matrix composite structures (components) which are lightweight, very stiff, affordable, tight tolerance and space qualified (JSPP 3-128).

Atmospheric Remote Sensing and Assessment Program (ARSAP). is a Naval program whose principle objective are to conduct observations of the middle and upper atmosphere of quantities of interest to the DoD and to satisfy national needs in the area of global change (JSPP 3-126).

Automated Charge Control at Geosynchronous Orbit (CHARGECON-GEO). is a Phillips Laboratory Geophysics Directorate experiment which monitors and controls the induced potentials caused by the space environment. The experiment will space qualify an automated charge control system. It is manifested as a STP secondary payload on a DSCS III satellite to be launched in 1995 (JSPP 3-125).

Advanced Technology Standard Satellite Bus (ATSSB). An ARPA project to integrate and demonstrate an advanced spacecraft bus that incorporates techniques to reduce satellite weight and cost, while achieving a high (greater than 50%) payload mass fraction. A FY'94 new start is currently under consideration (JSPP 3-124).

Air Borne Laser (ABL). See Directed Energy Weapons

Directed Energy Weapons (DEW). This is an BMDO concept designed to destroy ballistic missiles with a directed energy source, such as a high-powered laser, before the warheads become active or reenter the atmosphere. The concept can be applied in a variety of basing modes, such as space-based, ground-based, and airborne. Principally through the Phillips Laboratory, the Air Force DEW program is developing candidate technologies for both space-based and airborne laser weapons. SMC's Active Defense Program Office investigates the application of DEW as an integral part of various evolving strategic, national and theater defense systems. As a part of the Theater Missile Defense Program, and in cooperation with the Phillips Laboratory, SMC is initiating a project to develop and deploy a prototype airborne laser (ABL) weapon to destroy missiles during their boost phase (Space 12).

ELITE (Electric Insertion Transfer Experiment). will demonstrate system level electric orbit transfer vehicle (EOTV) technologies in a realistic mission scenario. ELITE is a Cooperative Research and Development Agreement (CRDA) venture with TRW that takes advantage of several ongoing technology programs within the DoD and NASA. ELITE will integrate a propulsion subsystem consisting of a 30 kW arc-jet engine (JSPP 3-122).

Extreme Ultraviolet Imaging Photometer. This Army program will collect data on the composition and behavior of the upper ionosphere to determine ionospheric effect on communications. The data ties into the STP ARGOS mission (JSPP 3-126).

Global Surveillance Satellite Technology Demonstration (GSSTD). This effort will demonstrate on-orbit sensors capability; user tasking of sensor independent of spacecraft control; sensor performance, robustness, and reliability; real-time targeting and identification; and on- and off-board data fusion (JSPP 3-124).

HERCULES. A tri-service program This program will utilize orbital platforms for ground and near-ground sensing. The Navy project will explore the feasibility of man-assisted orbital multispectrum imagery (MSI) for Army tactical applications (3-121).

High Altitude Balloon Experiments (HABE). These are BMDO sponsored Acquisition, Tracking, Pointing and Fire Control experiment restructured from ALTAIR. HABE experiments will be performed at high altitude in a near-space environment. HABE will answer a number of critical technology questions that addresses the feasibility of target acquisition, precision tracking, and beam pointing for Directed Energy Weapon systems (JSPP 3-123).

High Temperature Superconductivity Space Experiment (HTSSE). is a series of Navy lead space experiments to demonstrate the operation and advantages of high temperature super-conducting devices and sub-systems in the space environment. HTSSE II will demonstrate the integration of super-conducting and semiconducting devices operating near 70 Kelvin. HTSSE II will be launched in 1996 (JSPP 3-125).

LEAP (Lightweight Exoatmospheric Projectiles). This is a BMDO sponsored project that developed, integrated, and is now demonstrating technologies for the exoatmospheric interception and destruction of ballistic missiles (JSPP 3-123).

Magnetic Atmospheric X-Ray Imaging Experiment (MAXIE). MAXIE is an Office or Naval Research experiment which will measure the spatial distribution and temporal variations of X-ray emissions produced by energetic electrons between 4 and 50 keV; 100 km spatial resolution will be provided (JSPP 3-125).

Microelectronics and Photonics Test Bed (MPTB). This program will be used to evaluate the performance of components planned for operational spacecraft in the space radiation environment. Technologies included in the MPTB are fiber optics, photonics, sensors, CCD's and focal plane arrays. Additionally, new microelectronic devices such as advanced microprocessors, memories, logic gates and A/D converters will be tested. MPTB is a joint Navy/Air Force program, funded by Navy SPAWAR, Air Force Phillips Laboratory and the Defense Nuclear Agency (JSPP 3-125).

Middle Atmosphere High Resolution Spectrograph Instrument (MAHRSI). This Navy program tests the use of UV to characterize the D and E regions of the ionosphere for low frequency communications, detection, and tracking. MAHRSI will fly as a STP secondary payload on Shuttle CRISTA-SPAS platform in 1993 (JSPP 3-126). MAHRSI is scheduled to fly annually.

Military Man in Space (Terra Scout/AOTF). This Army program will utilize manned orbital platforms for target recognition and develop data on the feasibility of man-assisted hyper-spectral ground target recognition. This target database incorporates lessons learned on the previous flight STS-44 (JSPP 3-126).

Polar Ozone and Aerosol Measurement II (POAM II). This Navy program measures ozone and constituents important in ozone photo-chemistry in the polar stratosphere. POAM was launched in 1993 as a STP secondary payload on the SPOT-3 Satellite (JSPP 3-126).

Remote Atmospheric and Ionospheric Detection System (RAIDS). This Navy program is designed to sense the global distribution of both the ionized and neutral density from 100 Km (E-region) to 1,000 Km (upper F-region) will be monitored using ultraviolet remote sensing techniques. The experiment will satisfy the C3I operational needs for ionospheric data within the DoD community. RAIDS is scheduled to fly in 1994 as a STP secondary payload on the NOAA-J mission (JSPP 3-126).

Polar Orbiting Geomagnetic Survey II (POGS II). is an experiment sponsored by the Navy Oceanographic Command which will demonstrate the feasibility of collecting global magnetic data on board a DMSP satellite in 1996 (JSPP 3-126).

Space-Based Laser (SBL). See Directed Energy Weapons

Space Test Experiments Platform (STEP) STEP-1 will investigate use of ionospheric ducts for communication and perform satellite drag model verification (JSPP 3-119). STEP-3 will demonstrate active vibration suppression, satellite attack warning, optical magnetic storage devices, and conduct materials experiments (JSPP 3-119).

Clementine I & II. Clementine I is a Ballistic Missile Defense Organization (BMDO) mission to test various spacecraft and sensor systems by means of a deep-space mission using a very small spacecraft. The Clementine I mission, launched in Winter, 1994, was planned to travel to the Moon, orbit and conduct remote sensing of the Moon, and then proceed on to a rendezvous with a near-Earth asteroid. Clementine II is still in a preliminary planning phase.

Space Test Program (STP). STP provides space flights for advanced DoD research and development experiments and prototype operation systems, and conducts in-space testing and control of DoD research and development satellites. The program acquires small space boosters and integrates and launches DoD payloads on these vehicles (Mission 17). (Contractors: Rockwell, TRW, Orbital, Sciences Corp. et al.) There are a variety of STP programs in progress; these include the following:

Advanced Research and Global Observation Satellite (ARGOS) . This STP mission consists of eight DoD experiments:

1. High Temperature Superconductivity space Experiment -Navy
2. Electric Propulsion Experiment (ESEX) - Air Force
3. Extreme Ultraviolet Imaging Photometer (EUVIP) - Army
4. Global Imaging Monitoring of the Ionosphere (GIMI) - Navy
5. High Resolution Atmospheric Airglow Spectrometer - Navy
6. Space Dust Experiment (SPADUS) - Navy
7. Unconventional Stellar Aspect Experiment - Army
8. Critical Ionization Velocity (CIV) - Air Force

The ARGOS mission is scheduled for launch in early 1996 from Vandenberg using a Delta II launch vehicle.

Standoff Detection (CBW). This Army program will demonstrate the capability to detect Nuclear Biological and Chemical (NBC) threats on the tactical battlefield from a low earth orbiting satellite. Preliminary meetings with STP officials are on-going (JSPP 3-126).

TAOS. Technology for Autonomous Operational Survivability (TAOS) program will conduct a series of space experiments. The objectives of the TAOS mission are:

1. To develop and demonstrate advanced spacecraft technologies
2. Demonstrate modularity and standardization to enhance space system capability, and
3. Expedite the transition of the new technologies to space system developers and operational users.

TAOS will be launched in early 1994 from Vandenberg Air Force Base, California, on a Taurus launch vehicle.

TOPAZ. Under a Memorandum of Understanding (MOU) with BMDO and DOE, the Air Force's Phillips Laboratory (PL) is the test director for the Thermionic Systems Evaluation Test. This is an electrical test of an unfueled Russian TOPAZ II space nuclear power system. PL is responsible for the "balance-of-plant" for a 10-40 kilowatt of energy space nuclear power system. Balance-of-plant includes the major subsystems with the exception of the reactor core. DOE is responsible for the reactor core. Based on successful technology demonstrations and detailed safety reviews a "go" or "no go" decision for a flight demonstration will be made in Fiscal Year 1995.

Thermal Management for Composite Structures. Thermal Management for Composite Structures will demonstrate the ability to selectively conduct/channel heat flow in specific regions and insulate/inhibit in others using composite materials features induced by new manufacturing technologies (JSPP 3-128).

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Section 4
Excursions from the Baseline

4.1 Overview

For the Space R&D Task Group, three broad options were considered as excursions to the baseline model, including the development of several significant new systems in the post-2000 time-frame in all three sectors, paralleled by increasing support to U.S. industry by related (predominantly civilian) government space R&D programs. For example, in commercial space a new cargo-carrying vehicle was projected, to served growth in LEO communications systems, in commercial Earth observing and/or remote sensing, and in materials processing in space (beginning in the post-2003 time-frame). Similarly, in the civilian government sector, the excursions forecast new systems for Mission to Planet Earth (e.g., geostationary platforms following completion of the initial EOS), for Space Science (such as Next Generation Space Observatories in post-2008), for Human Exploration and Space Development (such as replacement of the Shuttle by an HRV), as well as growth in space technology efforts in ground-based R&D and technology flight experiments. Finally, for DoD, excursion projections included launch and operations of GPS II for improved navigation, new multispectral Surveillance Systems, a Next Generation Launch System, potential deployment of Missile/Theater Defense Systems, and classified missions and programs appropriate for the excursion.

The Space Operations Task Group introduced an SSTO space launch and recovery system as an excursion to the baseline mission requirements model. The rationale for this was two-fold: the 1993 NASA Access to Space Study recommends the SSTO concept as the preferred approach to future space operations, and this "leapfrog technology: stresses facility needs to a larger extent than current conventional launch and recovery concepts. To assess the impact of SSTO operations and identify facility requirements, the working groups used previous studies, including the 1993 NASA Access to Space Study. These studies suggest that a significant number of facilities required for SSTO operations can be satisfied by major modifications to existing facilities. Any conclusions about complete facilities requirements, however, are highly dependent on the specific SSTO configuration being considered. While existing manufacturing facilities could, for the most part, support SSTO operations, some past launch systems studies conclude that operations costs can be reduced by locating manufacturing facilities in close proximity to major test sites or to the launch site.

The following paragraphs describe these excursions from the Baseline model and requirements.

4.2 Mission Model Excursions

4.2.1 Commercial Space Desired Missions (CsM-2)

The assessment of possible excursions from the baseline is intended to capture possible increases in requirements resulting from either higher-than-anticipated demand or from market-altering new technology developments. The excursions from the baseline requirements model for civilian commercial space activities follows the same four broad areas as the baseline; these excursions are summarized below.

The positive excursion from the baseline, includes over the next three decades (1) several significant new system developments in the post-2000 time-frame in the commercial space sector, and (2) increasing support with U.S. industry in government space R&D programs. In particular, the positive excursion requirements model includes the following activities:

1. **Launch Systems,** including development of new non-piloted cargo vehicle for commercial space applications (with operations in the 2004-2008 time-frame; potential fully reusable);

2. **Telecommunications,** including augmented commercial LEO communications systems and other space-derived services (e.g. global positioning);

3. **Earth Observing / Remote Sensing,** including transition of continuation of selected EOS data sets to provide sector suppliers; and,

4. **Materials Processing In Space,** including increased commercial materials processing and manufacturing operations beginning in the post-2003 time-frame,

The following paragraphs provide intermediate level details on the excursions from the baseline in the civilian commercial space requirements model, organized into three types: civilian commercial space missions (CsM-2), civilian commercial space upgrades (CsU-2), and civilian commercial space R&D programs (CsP-2)[3].

4.2.1.1 Launch Systems

Demand for medium-to-large vehicle launches of GEO telecommunications satellites may increase significantly during the period of interest (1993-2023), due to potential changes in the nature of the market and levels (or types) of satellite technologies. Such changes (described in section 4.2) could result in an overall level of demand of 15 or 20 internationally competed launches per year, with some cyclical variations. As in the baseline case, the U.S. is expected to maintain a 40% share of the total space launch market relative to foreign launch providers. Cyclical replacements of current and projected space systems account for the periodic surges in the number of launches in the mid-1990s and the 2004-2005 timeframe. Overall, the initial deployment and reconstitution phases of the of the system will include small vehicle launches for replacement of failed or inoperable satellite nodes (using a decline U.S. market share of 80%, 65%, and 50% for the 1990s, 2000s, and 2010s, respectively).

The commercial space positive excursion includes the development of a new non-piloted cargo vehicle for commercial space applications (with initial operations in the 2004-2008 time-frame). This vehicle would probably be an advanced technology (low cost operations) ELV, but has the potential to be fully reusable, depending on government-sponsored R&D.

Immediate Timeframe (1993-1998). In the immediate future, there are no major changes in the excursion. For example, the key new launch requirement beyond GEO system upgrades is in baseline 'big' LEO requirements that are initially based on a notional system of 48 satellites with an 8-year service life (with first deployment in 1998).

Near-Term (1999-2003). In the near-term, no change from the baseline with the exception of meeting launch requirements for an additional plane of satellites in the 'big' LEO constellation (see below).

Intermediate-Term (2004-2013). In the intermediate timeframe, there are no significant changes from the baseline.

[3] Note that except where explicitly stated, it is assumed that these 'excursions' are additional activities beyond the baseline requirements model. As such, they do not replace activities in the baseline. For the total level of activity in the forecast of the future represented by the excursion, the baseline requirements model activities must be added.

Far-Term (2014-2023). In the far-term, a new 'big' LEO constellation is launched (2014). Foreign launch providers are expect to participate in the launch of each major block changes (occurring every 16 years) for telecommunications satellite systems.

4.2.1.2 Telecommunications

The excursion from the baseline includes the private development of augmented commercial LEO communications systems and other space-derived services (e.g. global positioning). Moreover, market demand for new services could increase beyond baseline projects in the areas of Direct Broadcast Satellite (DBS) systems and GEO-based mobile communications services, particularly in the mid-term.

GEO Systems. For example, greater system interconnectivity between ground- and space-based networks could also lead to unanticipated demand (leading to more Ka-Band applications, advanced spacecraft, and more advanced on-board processing). Demand may very likely increase beyond anticipated levels in the Pacific Rim and the Third World (for both new and standard services), particularly as these areas develop economically and begin to modernize telecommunications infrastructure. Such regional demand would likely occur as follows:

- increased demand in the Asia / Pacific (and Pacific Rim) region, Eastern Europe, and former Soviet Union (FSU) in the late 1990s;
- increased demand in Central and South America from 2006 to 2010; and,
- increased demand in Africa from 2016 to 2020.

In addition, new technologies may also stimulate demand through increases in service efficiency (and resulting cost reductions). These technologies are sketched in Section 4.2 below.

LEO Systems. Also as noted, market demand is projected in the excursion to lead to augmented LEO systems. This increased market demand will be partially due to the economic development of the Asia Pacific region, Eastern Europe, the FSU, Central and South America, and Africa. (These are regions that will particularly suitable for LEO satellite services. Various new technologies — delineated in Section 4.2 — will be incorporated into the systems during minor and major block upgrades.

The following paragraphs provide the time-phased excursion forecast.

Immediate Timeframe (1993-1998). In the immediate future, there are no changes from the baseline requirements model due to the positive excursion.

Near-Term (1999-2003). In the near-term, there are significant changes due to the implementation of an additional 'small' LEO telecommunications satellite constellation. In particular, the excursion builds on the baseline model by adding an additional plane of satellites to the 'small' LEO constellation of 24 satellites provided for in the baseline as a part of the block upgrade of that systems.

Intermediate-Term (2004-2013). In the intermediate timeframe, the positive excursion projection includes additional satellite systems to meet future demand, including both LEO and GEO satellites. In particular, in the 2006 timeframe when the 'big' LEO constellation included in the baseline is 'block-upgraded', a new plane of satellites is added to the constellation due to increased demand.

Far-Term (2014-2023). In 2014, the positive commercial space excursion projects one additional 'big' LEO constellation with approximately 48 satellites (i.i., similar to the first constellation launched in the late 1990s).

4.2.1.3 Earth Observing / Remote Sensing

In the positive commercial space excursion, commercial remote sensing and Earth observing missions more rapidly evolve into a meaningful and stable portion of the overall market. For example, one activity that could be included would be the continuation of selected EOS data sets by private sector suppliers.

Immediate Timeframe (1993-1998). In the immediate future, there are no changes from the baseline requirements model due to the positive excursion.

Near-Term (1999-2003). In the near-term, moderate increases in activities are projected.

Intermediate-Term (2004-2013). In the intermediate timeframe, a continuation of moderate levels of activity are projected.

Far-Term (2014-2023). In the far-term, significant increases in commercial remote sensing and Earth observing missions are projected as a part of the positive excursion.

4.2.1.4 Materials Processing In Space

In the positive commercial space excursion, commercial in-space materials processing and manufacturing operations more rapidly evolve into a meaningful and stable portion of the overall market. The positive excursion includes increased commercial in-space materials processing and manufacturing operations beginning in the post-2003 time-frame. Demand for microgravity payloads is projected to be affected by increase government support of and cooperation with commercial microgravity experimentation. In addition, to the areas identified in the baseline, microgravity activities will increase the areas of biotechnology and genetics research.

Immediate Timeframe (1993-1998). In the immediate future, there are no changes from the baseline requirements model due to the positive excursion.

Near-Term (1999-2003). In the near-term, moderate increases in activities are projected.

Intermediate-Term (2004-2013). In the intermediate timeframe, a continuation of moderate levels of activity are projected.

Far-Term (2014-2023). In the far-term, significant increases in commercial in-space materials processing are projected as a part of the positive excursion.

4.2.2 Civilian Government Desired Missions (CgM-2)

The excursions of the requirements model for civilian government space activities follows the same four broad areas used in the baseline case. Over the next three decades, these include: (1) several significant new system developments in the post-2000 time-frame, (2) increasing technology content and required R&D for flight programs, and (3) increasing involvement with U.S. industry in R&D programs. In particular, the positive excursion requirements model includes the following activities:

1. **Mission to Planet Earth / Earth Observing,** including (a) completion of the initial Earth Observing System (EOS) series, followed by a second series employing small- to moderate- scale polar platforms; with selected low-cost Geostationary platforms after 2008, and (b) NOAA operation of integrated Earth/Weather remote sensing systems.

2. **Space Science/Mission From Planet Earth,** including - (a) major-science (at a moderate mission-cost) Next Generation Space Observatories in post-2008 (e.g.,TOPS-2), and (b) intensive robotic solar system exploration (in situ with selected sample return).

3. **Space Exploration and Development,** including (a) phase-out operation of Space Shuttle in the 2005 time-frame; early replacement with Highly Reusable Vehicle (HRV) for crew and cargo (Access to Space Option 3-class), (b) development and operations of international redesigned space station, through 2014 timeframe, then evolution of program with new elements and continuing international participation, (c) DOT/FAA operation of jointly-managed follow-on GPS constellation, (d) evolution of telecommunications systems and/or the DSN with optical communications, and (e) Lunar Outpost development in 2013-2018 (including HLLV development), with preparation in 2014-2023 time-frame for later human missions to Mars.

4. **Space Technology,**[4] including increased ground-based R&D and technology flight experiments to support mission programs listed above, and increase R&D to support increased commercial space activities. (See Section 4.4.)

The following paragraphs provide intermediate level details on the excursions from the baseline in the civilian government space requirements model, organized into three types: civilian government space missions (CgM-2), civilian government space upgrades (CgU-2), and civilian government space R&D programs (CgP-2).[5]

4.2.2.1 Mission to Planet Earth / Earth Observing

Earth Observing System. The positive excursion includes completion of the initial Earth Observing System (EOS) series, followed by a second series employing small- to moderate- scale polar platforms; with selected low-cost Geostationary platforms after 2008.

Immediate Timeframe (1993-1998). No adjustments to the baseline requirements model are included in the immediate future.

Near-Term (1999-2003). In the near-term, no adjustments to the baseline requirements model are included in the excursion.

Intermediate-Term (2004-2013). In the intermediate timeframe, in addition to the continuation of the EOS series with small LEO polar spacecraft, selected moderate-scale GEO missions are projected.

Far-Term (2014-2023). In the far-term, the mix of LEO and GEO platforms will continue.

[4] In 1990-1991, NASA's Office of Aeronautics and Space Technology conducted a broadly-based examination of the potential content (over 20 years) of a significantly expanded civilian government space R&D program, a summary of these results is documented in the 1991 Integrated Technology Plan.

[5] Note that except where explicitly stated, it is assumed that these 'excursions' are additional activities beyond the baseline requirements model. As such, they do not replace activities in the baseline. For the total level of activity in the forecast of the future represented by the excursion, the baseline requirements model activities must be added.

Operational Weather/Earth Observing Satellites. The model also includes the addition of NOAA operation of integrated Earth/Weather remote sensing systems;

Immediate Timeframe (1993-1998). No adjustments to the baseline requirements model are included in the immediate future.

Near-Term (1999-2003). In the near-term, no specific adjustments to the baseline requirements model are projected.

Intermediate-Term (2004-2013). In the intermediate timeframe, no specific adjustments to the baseline requirements model are projected.

Far-Term (2014-2023). In the far-term, no specific adjustments to the baseline requirements model are projected.

4.2.2.2 Space Science/Mission From Planet Earth

Astrophysics and Planetary Astronomy Missions. The positive excursion includes major-science (at a moderate mission-cost) missions, such as "next generation space observatories" in the post-2008 timeframe.

Immediate Timeframe (1993-1998). No adjustments to the baseline requirements model are included in the immediate future.

Near-Term (1999-2003). In the near-term, the beginning of Lunar surface science missions is a key element of the excursion, including concepts such as the Lunar Transit Telescope (LTT) and the Lunar Ultraviolet Telescope Experiment (LUTE).

Intermediate-Term (2004-2013). In the intermediate timeframe, major-science-goal missions — but at a moderate-mission-price — are the major theme in the positive excursion for astrophysics and planetary astronomy missions. Such mission concepts could include observatories across a broad spectrum (RF, submillimeter, IR, visible, UV, and higher), and with distributed collecting areas (e.g., interferometric approaches.) Specific opportunities would include one of two approaches to space interferometry - either the initial elements in a Lunar interferometric array (with later growth and development), or a more capable (initially) single structure free-flying interferometry. (These may be either Michelson or other type interferometer systems.)

Far-Term (2014-2023). In the far-term, the positive excursion assumes a continuation of the intermediate term increased level of activities, with additional emphasis on Lunar surface based systems and science coupled to the projected human return to the Moon (see the discussion below). Specific opportunities could include: a large space telescope (as a follow-on the the HST), and a major capability gravitational radiation observatory.

Space Physics Missions.

Immediate Timeframe (1993-1998). No adjustments to the baseline requirements model are included in the immediate future.

Near-Term (1999-2003). In the near-term, no major adjustments to the baseline requirements model are projected.

Intermediate-Term (2004-2013). In the intermediate timeframe, a key major mission that is key to space physics science objectives is the Solar Probe mission, that would fly a single spacecraft to within a few (e.g., 3-5) solar radii of the Sun's photosphere. High temperature systems and a large, low-mass thermal protection systems would characterize the mission, coupled to advanced communications and power technologies.

Far-Term (2014-2023). In the far-term, it is projected that a major space physics mission may be implemented such as an interstellar space probe (for example, a effort of the Thousand AU (TAU) mission type. The specifics of the mission concept will be largely technology driven, depending on the development of enabling technologies in the areas of space nuclear power and nuclear electric propulsion (NEP).

Planetary Exploration Missions.

Immediate Timeframe (1993-1998). No adjustments to the baseline requirements model are included in the immediate future.

Near-Term (1999-2003). In the near-term, no adjustments to the baseline requirements model are included.

Intermediate-Term (2004-2013). In the intermediate timeframe, intensive robotic solar system exploration (in situ with selected sample return) are added to the baseline model. In particular, small-scale, high technology Mars Sample Return (MSR) and Comet Nucleus Sample Return (CNSR) Missions are projected in the positive excursion. Also in this timeframe, the beginnings of implementation of a moderate-cost version of the TOPS-2 project would begin. This mission might be either space-based or Lunar surface based, but would probably entail multiple moderate-scale telescopes in an interferometric array.

Far-Term (2014-2023). In the far-term, intensive robotic Mars exploration missions continue. In addition, the implementation of a moderate-cost version of the TOPS-2 project would continue. This mission might be either space-based or Lunar surface based, but would probable entail multiple telescopes in an interferometric array.

4.2.2.3 Space Exploration and Development

Access to Space. In the positive excursion, the phase-out of Space Shuttle operations in the 2005 time-frame is included, with early replacement of the Shuttle by a Highly Reusable Vehicle (HRV) for crew and cargo. (This element of the model follows from the recent NASA Access to Space study, Option 3).

Immediate Timeframe (1993-1998). No adjustments to the baseline requirements model are included in the immediate future.

Near-Term (1999-2003). In the near-term, development and demonstrations of technologies for an HRV would take place (see the discussion in Section 4.4). Possible flight demonstration of an operational, unpiloted cargo version of an HRV is an option in the 2000-2002 timeframe.

Intermediate-Term (2004-2013). In the intermediate timeframe, the HRV would be implemented as a replacement to the Space Shuttle transportation system, with both cargo (unpiloted) and crew versions of the systems possible.

Far-Term (2014-2023). In the far-term, HRV operations would continued.

Space Station. In the positive excursion, continuing development and evolution of the international Space Station is projected in the farther term, including:

Immediate Timeframe (1993-1998). No adjustments to the baseline requirements model are included in the immediate future.

Near-Term (1999-2003). In the near-term, no adjustments to the baseline requirements model are included.

Intermediate-Term (2004-2013). In the intermediate timeframe, No adjustments to the baseline requirements model are included.

Far-Term (2014-2023). In the far-term, the international Space Station would be substantially augmented with new systems to reduce operations costs and extend services.

Additional Civilian Government Space Services and Operations

Immediate Timeframe (1993-1998). No adjustments to the baseline requirements model are included in the immediate future.

Near-Term (1999-2003). In the near-term, in this positive excursion, the DOT/Federal Aviation Administration (FAA) (in cooperation with the DoD) is projected to develop and begin launch of a new constellation of GPS follow-on spacecraft to provide integrated position, location and navigation services for U.S. commercial and government applications.

Intermediate-Term (2004-2013). In the intermediate timeframe, the deployment of the civilian GPS follow-on constellation is completed.

Far-Term (2014-2023). In the far-term, operations of the civilian GPS follow-on constellation continue with periodic satellite replacements and block upgrades, as required.

Mission Operations and Telecommunications

The model include evolution of overall telecommunications technology (including Earth-orbiting satellite-to-satellite links) and the NASA DSN with optical communications.

Immediate Timeframe (1993-1998). No adjustments to the baseline requirements model are included in the immediate future.

Near-Term (1999-2003). In the near-term, no adjustments.

Intermediate-Term (2004-2013). Late in the intermediate timeframe, multiple small-scale ground based receivers for optical deep space communications would be emplaced.

Far-Term (2014-2023). In the far-term, installation of multiple small-scale ground based receivers for optical deep space communications would be completed.

Deep-Space Human Exploration

The positive excursion includes the beginnings of significant levels of deep-space human exploration activities, including precursor programs, Lunar Outpost development in the 2013-2018 timeframe (including HLLV development), and preparation for later human missions to Mars in the 2014-2023 time-frame.

Immediate Timeframe (1993-1998). No adjustments to the baseline requirements model are included in the immediate future.

Near-Term (1999-2003). In the near-term, smaller-scale precursor missions focusing on the utilization of the Moon as a platform for space science (such as the Lunar Ultraviolet Telescope Experiment (LUTE); see the discussion above), and preliminary robotic exploration of Mars are projected in the excursion.

Intermediate-Term (2004-2013). In the intermediate timeframe, the excursion projects preparation for a later human return to the moon to establish an outpost. In addition, significant Lunar surface based space science missions would be emplaced in this time frame. Target mission opportunities include an initial Lunar Transit Telescope (LTT) early in the period, and extend to a multiple aperture Lunar-based optical interferometer (see the discussion of astrophysics missions). Significant robotic Mars missions would be implemented during this period (e.g., MSR). During this period, significant preparation programs would be conducted in advance of the initial human missions to the Moon.

Far-Term (2014-2023). In the first years of the period, the excursion projects a series of human missions to establish a permanent outpost on the Moon. These initial missions would be implemented using existing launch systems, with concurrent development of a Heavy Lift Launch Vehicle (HLLV) for use in Lunar outpost emplacement. For NFS planning purposes, key elements of the projected Lunar mission scenario include the following:

- High-performance, low-cost LEO to low Lunar orbit transportation systems (possibly reusable space transfer vehicle (STV) type, possibly expendable upper stage type)
- High-performance, low-cost Lunar lander systems, capable of precision landing maneuvers, extended duration Lunar surface operations and/or dormancy, followed by ascent to low Lunar orbit
- Advanced, light-weight and low maintenance extravehicular activity (EVA) systems for Lunar surface use, including surface mobility systems (e.g., rovers) for personnel transport and telerobotics operations
- Low-cost, locally deployable Lunar habitat systems (one possible concept would involve use of inflatable structures for volume in conjunction with more standard modules)
- High specific-power Lunar surface power systems, including both solar arrays, regenerative fuel cells and selected nuclear power sources (e.g., RTG-type systems)[6]
- Closed (or very nearly closed) regenerative life support systems (with an initial focus on physical-chemical life support)

During the same period, preparations are projected for an eventual human mission to Mars. In general, the system concepts (and associated technology R&D areas) projected for this effort are assumed to be parallel and/or largely common with those needed for the Lunar outpost. In particular, it is assumed that the HLLV developed to support Lunar outpost emplacement would also be used for later human Mars missions. These preparations are described in more detail below in the section concerning R&D programs.

[6] The question of R&D and facilities associated with large-scale power systems for use in major Lunar surface operations (such as in situ resource processing) should be treated as a separate, special topic. If treatment is deemed timely for the Phase 0 NFS, two potential cases should be addressed (in order of priority): (1) nuclear reactor power, and (2) laser beamed power (Earth-based).

4.2.3 Military Desired Missions (MM-2) Excursions/Emphasis Military Missions

If the budget permits, the programs listed below are the first desirable additions to our capabilities.

4.2.3.1 Surveillance / Earth & Weather Observing

Brilliant Eyes (BE) I, and Brilliant Pebbles (BP). The Ballistic Missile Defense Organization (BMDO) develops systems to provide defense against ballistic missile attacks. Brilliant Eyes is a space-based surveillance system used to detect and track ballistic missiles. Brilliant Pebbles is a space-based weapon system designed to intercept and destroy ballistic missiles before they reenter the atmosphere. (Contractors: TRW, Rockwell, Martin Marietta, et al.) Some of the key technical areas include:

- Contamination Control System Technology
- Focal Plane / System Technology
- Laser Communications / System Technology
- Propulsion / System Technology
- Spacecraft Power / System Technology
- Data Processors
- Energy Storage
- Environments (hostile, natural, and passive)
- Heat Transfer / Dissipation
- Inertial Pseudo Star Reference Unit
- Kinetic Energy Weapons
- Orbit Transfer and Maneuvering Propulsion
- Photovoltaics
- Space Electronics and Software
- Space Thermal Technology / Cryogenic Technology
- Strategic Guidance
- Structures
- Techniques Active
- Thermophysics / Plumes

Global Theater Surveillance System (GTSS). GTSS is a tactical theater surveillance system. Concepts include infrared, multispectral optical and active radar systems. Some of the key technical areas for the GTSS excursion mission option include:

- Energy Storage
- Environments (hostile, natural, and passive)
- Inertial Pseudo Star Reference Unit
- Photovoltaics
- Space Electronics and Software
- Space Thermal Technologies / Cryogenic Technology
- Strategic Guidance
- Structures
- Techniques Active
- Thermophysics / Plumes

Visible Light Systems I & II. Some of the key technical areas for the Visible Light Systems (I and II) excursion mission option include:

- Space Surveillance / System Technology
- Data Processors
- Energy Storage
- Environments (hostile, natural, and passive)
- Heat Transfer / Dissipation
- Optoelectronics / On-Array Signal Processors
- Space Electronics and Software
- Structures
- Techniques Active

4.2.3.2 Missile Offense and Launch Systems

Space Lifter. The Space Lifter program is a DoD-focused national program to develop a new family of launch vehicles for medium to heavy payloads. The goal of the Space Lifter program is to meet the national security launch needs and form the basis for civil and commercial launch systems of the next century. The major thrusts of the program are to make significant improvements in operability and reliability while reducing launch costs (Mission 16). (Contractors: Various.) Some of the key technical areas include:

- Advanced Cryogenic Engine
- Cryogenic Solids
- Energy Storage
- Environments (hostile, natural, and passive)
- Heat Transfer / Dissipation
- High Energy Density Matter (HEDM)
- Space Electronics and Software
- Space Launch Propulsion / National Launch System
- Structures
- Synthesis and Stabilization
- System Support
- Techniques Active
- Thermophysics / Fundamental Technologies

Tactical Support System. Some of the key technical areas for the Tactical Support System excursion mission option include:

- Global Theater Surveillance System (GTSS) Technology
- Energy Storage
- Environments (hostile, natural, and passive)
- Heat Transfer / Dissipation
- Space Electronics and Software
- Structures
- Techniques Active

4.3 Excursion Mission Upgrades (Space R&D)

4.3.1 Commercial Space Desired Upgrades (CsU-2)

The following paragraphs sketch the upgrades projection for the positive excursion across all four areas of commercial space activity. These parallel the upgrades projected for the baseline.

Immediate Timeframe (1993-1998). In the immediate future, there are no changes as a part of the positive excursion.

Near-Term (1999-2003). In the near-term, In the near-term, there are significant changes due to the implementation of an additional 'small' LEO telecommunications satellite constellation. In particular, the excursion builds on the baseline model by adding an additional plane of satellites to the 'small' LEO constellation of 24 satellites provided for in the baseline as a part of the block upgrade of that systems. During this timeframe, periodic upgrades of commercial remote sensing and microgravity materials processing mission systems are projected.

Intermediate-Term (2004-2013). In the intermediate timeframe, regular upgrades of LEO and GEO telecommunications satellites systems are projected. During this timeframe, periodic upgrades of commercial remote sensing and microgravity materials processing mission systems are projected.

Far-Term (2014-2023). In the far-term, regular upgrades of LEO and GEO telecommunications satellites systems are projected. During this timeframe, periodic upgrades of commercial remote sensing and microgravity materials processing mission systems are projected.

4.3.2 Civilian Government Desired Upgrades (CgU-2)

Because of the exploratory nature of most civilian government space activities, upgrades of capability are (in most cases) listed as a part of the baseline mission descriptions provided above in section 3.2.2.

4.3.3 Military Upgrades Two (MU-2) Excursions/Emphasis Military Upgrades

These are the desired upgrades to current and projected systems.

4.3.3.1 Communication and Navigation

Global Positioning Satellite (GPS) II F. Some of the key technical areas for the GPS replacement excursion mission option include:

- Atomic clocks
- Cross-Links
- Anti-jam technologies
- Satellite Control / System Technology
- Data Processors
- Energy Storage
- Environments (hostile, natural, and passive)
- Heat Transfer / Dissipation
- Photovoltaics
- Space Electronics and Software
- Structures
- Techniques Active

UHF Follow-On (UFO) Replacement. Some of the key technical areas for the UHF Follow-On (UFO) Replacement excursion mission option include:

- Communication Systems
- MILSATCOM Technology
- Satellite Control / System Technology

- Energy Storage
- Environments (hostile, natural, and passive)
- Heat Transfer / Dissipation
- Inertial Pseudo Star Reference Unit
- Space Electronics and Software
- Strategic Guidance
- Structures
- Techniques Active

4.3.3.2 Surveillance / Earth & Weather Observing

Advanced LANDSAT. Some of the key technical areas for the Advanced LANDSAT excursion mission option include:

- Theater Surveillance System
- Remote Sensing System Technology
- Space Surveillance / System - Technology
- Energy Storage
- Environments (hostile, natural, and passive)
- Photovoltaics
- Space Electronics and Software
- Structures
- Techniques Active

Brilliant Eyes II. Some of the key technical areas for the Brilliant Eyes excursion mission options include:

- Contamination Control
- Focal Plane / System Technology
- Laser Communications / System Technology
- Spacecraft Power / System Technology
- Data Processors
- Energy Storage
- Environments (hostile, natural, and passive)
- Heat Transfer / Dissipation
- Inertial Pseudo Star Reference Unit
- Kinetic Energy Weapon
- Orbit Transfer and Maneuvering Propulsion
- Photovoltaics
- Space Electronics and Software
- Space Thermal Technology / Cryogenic Technology
- Strategic Guidance
- Structures
- Techniques Active
- Thermophysics / Plumes

4.3.3.3 Missile Offense and Launch Systems

Integrated Satellite Control System (ISCS) to upgrade AFSCN. Some of the key technical areas for the ISCS upgrade include:

- Energy Storage
- Environments (hostile, natural, and passive)
- Inertial Pseudo Star Reference Unit

- Space Electronics and Software
- Strategic Guidance
- Structures
- Techniques Active

4.4 Excursion Mission-Supporting R&D Programs (Space R&D)

4.4.1 Commercial Space Research and Development Programs (CsP-2)

A variety of technology R&D programs are projected in the civilian commercial space positive excursion. These fall into two general categories: (a) advances which enable new market growth, and (b) advances which support increase efficiencies and lower costs in projected systems.

Immediate Timeframe (1993-1998). In the immediate future, the same technology developments projected for the baseline model will be required to support the augmented constellations projected.

Near-Term (1999-2003). In the near-term, there are several significant technology R&D areas that are key to increased GEO and LEO ('big' and 'small' constellations) commercial space telecommunications satellite activities in the 2004-2013 timeframe. These include:

- decoupled antenna technologies and RF beacons for attitude determination (replacing conventional ADC devices such as gimbals and reaction wheels), allow improved telemetry, tracking and control; and,

- Laser-based cross-links between satellites, allowing multi-region signal transmission while eliminating some ground stations.

Additional technologies needed for LEO systems include:

- on-board signal regeneration and processing (thereby increasing data transfer rates, signal quality, and general flexibility of mobile services); and,

- extensive use of composite materials in spacecraft structures.

Intermediate-Term (2004-2013). In the intermediate timeframe, new telecommunications satellite technologies that must be developed to be available for application in the 2010-2015 timeframe include:

- Gallium Arsenide solar cells, which will reduce the weight of solar arrays and allow higher efficiency in PV conversion;

- electric (ion) propulsion systems for orbit transfer and station-keeping, allowing reductions in propellant and overall spacecraft weight[7] ; and,

- Gallium Arsenide solid state power amplifiers (SSPAs) for both Ku- and Ka- band applications, allowing lower weights, higher reliability, and improved signal-to-noise ratio (SNR) performance.

Also, to support the implementation of larger LEO constellations at reasonable costs, the development of onboard health monitoring system technologies is projected to occur earlier than in

[7] Note: ion propulsion would be applicable only on a limited scale for 'small' LEO systems.

the baseline.

Far-Term (2014-2023). In the far-term, continuing advancements are required in areas such as telecommunications systems, spacecraft bus materials and systems, and operations technologies. In particular, technologies for high frequency video applications are projected to be needed for use in 2022-timeframe satellite replacements.

4.4.2 Civilian Government Desired Space Technology R&D Programs (CgP-2)

The positive excursion for civilian government space R&D programs includes both ground-based technology development and in-space research activities (either at the basic science level (e.g., microgravity research) or at the technology validation level (e.g., in-space technology experiments).

4.4.2.1 Technology Research and Development

The civilian government space excursion from the baseline includes both increased ground-based R&D and technology flight experiments to support civilian government mission programs listed above and increased support for commercial space activities (following on the NACA model).

Immediate Timeframe (1993-1998). In the immediate future, a central theme in the positive excursion to the baseline mission model is the development of a new, Highly Reusable Vehicle (HRV) for the transport of crews and cargo to LEO (replacing the Space Shuttle in the 2005 timeframe). The current reference concept for planning purposes is assumed to be a rocket-propelled, vertical-takeoff and horizontal (winged) landing, Single-Stage-To-Orbit (SSTO) HRV. Significant R&D programs would be needed in the immediate future to support this development, include those in the following list.

- For Performance Feasibility:

  - Aluminum Lithium Cryogenic Tanks
  - Graphite composites for the Primary vehicle structure
  - Tri-propellant engines

- For additional design margin and reduced sensitivity to later design changes and/or issues:

  - Composite reusable hydrogen and RP (hydrocarbon rocket propellant) tanks

- For Operations and Cost Feasibility:

  - Reusable integrated tank/insulation/thermal protection system (TPS)
  - Lightweight, durable TPS
  - Integrated vehicle health monitoring
  - Adaptive software/avionic
  - highly operable systems

(Sections 3.5.2 and 4.4.2 provide relevant information on the technology areas in which government support for commercial space activities is projected.)

Near-Term (1999-2003). In the near-term, the positive excursion for civilian government space activities leads to R&D programs in support of several program areas. First, there will be continuing development in support of an HRV (see above). Another major theme in this timeframe would be R&D to support the development of moderate-cost (but major science objective) missions in the 2004-2013 timeframe. At a top-level, these may be divided into two technical summary areas: technologies for deep-space (largely in situ) science missions (planetary or space physics) and technologies for observatory science missions (typically in Earth orbit, but potentially elsewhere).

Some of the key technology areas for future major/moderate-cost science deep-space mission development include:

- Low-cost, high-specific impulse upper stages (e.g., solar electric propulsion (SEP) for reduced space launch and transportation costs[§]
- Highly autonomous spacecraft systems for low operations costs
- Miniaturized onboard sensor and robotic systems (e.g., to enable small sample return missions)
- Low-mass, long-life thermal and power management systems
- Low-cost, high-data transmission telecommunications (including both increased data compression capabilities, increased onboard processing, and higher-rate and/or lower cost data links)

Similarly, some of the key technology areas for future major/moderate-cost science observatory missions include:

- Light-weight, highly stable, low-cost observatory structures and materials
- Large single aperture and interferometric array R&T (including adaptive optics and interferometry (both optical and heterodyne)
- Low-cost, high-specific impulse upper stages (e.g., solar electric propulsion (SEP) for reduced space launch and transportation costs)
- Highly autonomous spacecraft systems for low operations costs
- Low-cost, high-data transmission telecommunications (including both increased data compression capabilities, increased onboard processing, and higher-rate and/or lower cost data links)

(Sections 3.5.2 and 4.4.2 provide relevant information on the technology areas in which government support for commercial space activities is projected.)

Intermediate-Term (2004-2013). In the intermediate timeframe, the positive excursion for civilian government space activities leads to continuation of efforts in the technical areas described above. In addition, R&D programs in support of several out-year program areas would be needed, including support for: evolution and continuing development of the international Space Station; development of technologies for telecommunication systems advances (such as optical communications for space-to-ground and space-to-space applications); and major deep-

[§] For purposes of the Phase 0 NFS assessment, the question of Nuclear Electric Propulsion (NEP) and associated nuclear reactor power for deep space robotic missions may be better deferred; if issues do arise requiring treatment, however, the assumption should be that reactor power levels on the order of 50-100 kilowatts, with lifetimes on the order of 10 years, are required.

space science missions; and preparation for a human return to the Moon.

Some of the key technology areas for development will include:

For Lunar Missions:

- High-performance, low-cost orbit transfer vehicle propulsion (including both chemical and electric propulsion technologies, as well as the aerothermodynamics and thermal protection systems associated with a reusable, aerobraking STV)
- High-precision landing vehicle GN&C
- Advanced, light-weight Lunar EVA systems
- Low-cost, locally deployable Lunar habitat systems
- Technologies associated with in situ resource utilization (ISRU), including chemical processing, robotic mining systems, and others
- High specific-power Lunar surface power systems, including both solar arrays, regenerative fuel cells and selected nuclear power sources (e.g., RTG-type systems[9]
- Closed (or very nearly closed) regenerative life support systems (with an initial focus on physical-chemical life support)

For Mars Mission Preparation[10] :

- Long-term human space flight research (including human factors, microgravity effects, etc.)
- Aerothermodynamics and TPS technologies associated with both orbit insertion at Mars and precision landing onto the Mars surface.

(Sections 3.5.2 and 4.4.2 provide relevant information on the technology areas in which government support for commercial space activities is projected.)

Far-Term (2014-2023). In the far-term, the major additional technology R&D area added in the positive excursion is preparation for a later human mission to Mars. The key technology R&D areas will parallel those cited for the intermediate term above. An additional area of technology R&D that would be added would be an increased emphasis on bioregenerative life support systems (including both plant growth and biomass processing type technologies). (Sections 3.5.2 and 4.4.2 provide some summary information on the technology areas in which government support for commercial space activities is projected in this timeframe.)

[9] The question of R&D and facilities associated with large-scale power systems for use in major Lunar surface operations (such as in situ resource processing) should be treated as a separate, special topic. If treatment is deemed timely for the Phase 0, two potential cases should be addressed (in order of priority): (1) nuclear reactor power, and (2) laser beamed power (Earth-based).

[10] In general, the issues associated with the necessary facilities to support nuclear propulsion R&D (either nuclear thermal propulsion (NTP) or nuclear electric propulsion (NEP)) for human missions to Mars should be treated as a separate, special topic (if treatment is, in fact, needed in the NFS). If treatment is needed, then for those purposes the following assumptions should be made: (1) NTP should be assumed to be a solid core system (either NERVA-type or PBR) and (2) NEP should be assumed to be for cargo transport with power levels in the 300 kW to 5 mW range.

4.4.2.2 Technology Development Flight Experiments

The excursion includes selected NASA technology development flight experiments (on Shuttle, Station, etc.)

Immediate Timeframe (1993-1998). In the immediate future, the excursion includes increased R&D flight experiments and demonstrations to support increased commercial space activities (discussed above).

Near-Term (1999-2003). In the near-term, the excursion includes increased R&D flight experiments and demonstrations to support increased commercial space activities (discussed above).

Intermediate-Term (2004-2013). In the intermediate timeframe, the excursion includes increased R&D flight experiments and demonstrations to support increased commercial space activities (discussed above). Additional flight demonstrations and experiments to support development of a human deep-space missions (Lunar-focus) may be required.

Far-Term (2014-2023). In the far-term, the excursion includes increased R&D flight experiments and demonstrations to support increased commercial space activities (discussed above). Additional flight demonstrations and experiments to support development of a human deep-space missions (Mars mission-focus) may be required.

4.4.2.3 Microgravity Research Missions

Immediate Timeframe (1993-1998). In the immediate future, the excursion includes increased R&D to support increased commercial space activities (discussed above).

Near-Term (1999-2003). In the near-term, the excursion includes increased R&D to support increased commercial space activities (discussed above).

Intermediate-Term (2004-2013). In the intermediate timeframe, the excursion includes increased R&D to support increased commercial space activities (discussed above).

Far-Term (2014-2023). In the far-term, the excursion includes increased R&D to support increased commercial space activities (discussed above).

4.4.3 Military Desired R&D Programs (MP-2) Excursions/Emphasis Military Technology Areas

MP-2 is the list of technologies that need to be worked in the far term (post-2005), to support the programs of MM-2 and MU-2. Some of this work is on-going, and renaming it in this section is used to state need for increase emphasis. The required technologies are sorted along JDL taxonomy lines.

Astronics. The component R&D areas include:

- Algorithm Development
- Battle Damage Assessment Techniques
- Cross Links (> 1 Mega Bit/Sec) i.e. Laser or RF
- Light Weight Space Hard Optics
- Target Detection, Identification, and Classification Techniques

Electronics. The component R&D areas include:

- Extremely-High Frequency (EHF) Transmit/Receive (TR) modules
- Light Weight Extremely-High Frequency (EHF) Phase Array Antennas
- On-Board 100 Mega Flop Computers (Near-Tera)
- On-Board Space Computers (> 1 Giga Flop for intermediate term)
- Space Qualified Transmit/Receive modules (L-X band)
- Hyper/Multi Spectral Imaging & Processing

Guidance, Navigation and Control. The component R&D areas include:

- Cross Link Network for World-Wide Satellite Command and Control
- EHF Tracking, Telemetry and Control
- Ground Based Artificial Intelligence
- Improved Satellite Command and Control Interfaces
- Mobile Satellite Command & Control for Theater Operations

Power. The component R&D areas include:

- High Energy Density Batteries
- High Power Distribution and Conditioning Systems

Propulsion. The component R&D areas include:

- Hybrid Engines
- Single Stage to Orbit (SSTO) engine development & test
- Tri-propellent development

Sensors. The component R&D areas include:

- Large Scale Focal Plane Arrays
- Light Weight Phase Array Antennas
- On-Focal Plane Array Signal Processing

Structures. The component R&D areas include:

- Light Weight Space Hard Optics
- Lightweight Structures

Survivability. The component R&D areas include:

- Anti Jam / Adaptive Nulling

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Section 5

Glossary of Acronyms

AACB	Aeronautical and Astronautical Coordination Board
ADC	Attitude Determination Control
AFSPACECOM	Air Force Space Command
AIM	Astrometric Interferometry Mission
AO	Announcement of Opportunity
ARPA	Advanced Research Projects Agency
ASTRO-2	Astronomy Observatory-2
AXAF	Advanced X-Ray Astronomical Facility]
AXAF (i)	AXAF (imaging)
AXAF (s)	AXAF (spectroscopy)
BE	Brilliant Eyes
BMDO	Ballistic Missile Defense Organization
BP	Brilliant Pebbles
CCDs	Charge-Coupled Devices
CgM-1	Civilian Government Missions (Baseline)
CgM-2	Civilian Government Missions (Excursions)
CgP-1	Civilian Government Mission-Supporting R&D Programs (Baseline)
CgP-2	Civilian Government Mission-Supporting R&D Program (Excursions)
C-GRO	Compton - Gamma Ray Observatory
CG	Civilian Government Mission, Planned System Upgrades (Baseline)
CgU-2	Civilian Government Mission, Planned System Upgrade (Excursions)
COMSTAC	Commercial Space Transportation Advisory Committee
CsM-1	Commercial Space Missions (Baseline)
CsM-2	Commercial Space Missions (Excursions)
CsP-1	Commercial Space Mission-Supporting R&D Programs (Baseline)
CsP-2	Commercial Space Mission-Supporting R&D Programs (Excursions)
CsU-1	Commercial Space Mission, Planned System Upgrades (Baseline)
CsU-2	Commercial Space Mission, Planned System Upgrades (Excursions
DBS	Direct Broadcast Satellite
DOC	Department of Commerce
DoD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DMSP	Defense Meteorological Satellite Program

DSP	Defense Support Program
DSCS	Defense Satellite Communications System
DSIA	Defense Information Systems Agency
DSN	Deep Space Network
EOS	Earth Observing System
EOSDIS	EOS Data and Information System
ESA	European Space Agency
FAA	(DOT) Federal Aviation Administration
FAST	Fast Auroral Snapshot Explorer
FEWS	Follow-on Early Warning System
FSU	Former Soviet Union
FUSE	Far Ultraviolet Spectroscopic Explorer
GBI	Ground-Based Interceptor
GBL	Ground-Based Laser
GEO	Geostationary Earth Orbit
GFO	GEOSat Follow-On
GN&C	Guidance, Navigation and Control
GOES	Geostationary Operational Environmental Satellite
GP-B	Gravity Probe-B
GPS	Global Positioning Satellite
GRP	Guidance Replacement Program
GTSS	Global Theater Surveillance System
HLLV	Heavy Lift Launch Vehicle
HRV	High Reusable Vehicle
HST	Hubble Space Telescope
ICBM	Intercontinental Ballistic Missile
IML	International Microgravity Laboratory
INSTEP	In-Space Technology Experiments Program
JCS	Joint Chiefs of Staff
JDL	Joint Directors of Laboratories
JSPP	Joint Services Program Plans
JUNO	The Joint Ultraviolet Night Sky Observer
LAGEOS	Laser Geodynamics Satellite
LDR	Large Deployable Reflector
LEO	Low Earth Orbit
LIDAR	Light Detection and Ranging
LITE	LIDAR In-Space Technology Experiment
LST	Large Space Telescope
LTT	Lunar Transit Telescope

LUTE	Lunar Ultraviolet Telescope Experiment
MAP	Mission Area Plan
MAPS	Measurement of Air Pollution from Satellites
MFPE	Mission From Planet Earth
MIDEX	Middle-Class Explorer (Missions)
MILSATCOM	Military Satellite Communication (architecture)
MLV	Medium Launch Vehicle
MM-1	Military Missions (Baseline)
MM-2	Military Missions (Excursions)
MP-1	Military Mission-Supporting R&D Programs (Baseline)
MP-2	Military Mission-Supporting R&D Programs (Excursions)
MSL	Microgravity Science Laboratory
MTPE	Mission To Planet Earth
MU-1	Military Missions, Planned System Upgrades (Baseline)
MU-2	Military Missions, Planned System Upgrades (Excursions)
NACA	National Advisory Committee on Aeronautics
NASA	National Aeronautics and Space Administration
NEAR	Near-Earth Asteroid Rendezvous (Mission)
NEP	Nuclear Electric Propulsion
NIST	(DOC) National Institute of Standards and Technology
NLS	National Launch System
NOAA	National Oceanographic & Atmospheric Administration
NORAD	North American Air Defense
NSF	National Science Foundation
NTP	Nuclear Thermal Propulsion
OCST	(DOT) Office of Commercial Space Transportation
OSL	Orbiting Solar Laboratory
OVLBI	Orbiting Very Long Baseline Interferometry
(Pluto) FFB	Pluto Fast Fly-By (Mission)
PBR	Pebble Bed Reactor
POEMS	The Positron Electron Magnetic Spectrometer
PV	Photovoltaic
R&D	Research and Development
R&T	Research and Technology
RADARSAT	Radar Satellite
REACT	Rapid Execution and Combat Targeting
RTG	Radioisotope Thermoelectric Generator
RTOP	(NASA) Research and Technology Operating Plan
SAF	Secretary of the Air Force

SAF/TE	SAF/Test and Evaluation
SAMPEX	Solar Anomalous Magnetospheric Particle Explorer
SAR	Synthetic Aperture Radar
SBI	Space-Based Interceptor
SBL	Space-Based Laser
SEARWG	Systems Engineering and Requirements Working Group
SEP	Solar Electric Propulsion
SIR-C	Shuttle Imaging Radar
SIRTF	Space Infrared Telescope Facility
SL	Space Lab
SMEX	Small-Class Explorer (Missions)
SMIM	Submillimeter Intermediate Mission
SNR	Signal to Noise Ratio
SOHO	Solar and Heliospheric Observatory (Mission)
SRL	Space Radar Laboratory
SSFF	Space Station Furnace Facility
SSPA	Solid State Power Amplifier
SSTO	Single Stage To Orbit
SSTO (R)	SSTO (Rocket Propulsion)
STIG	Space Technology Interdependency Group
STV	Space Transfer Vehicle
SWAS	Submillimeter Wave Astronomy Satellite
TAP	Technology Area Plan
TAU	Thousand Astronomical Unit (Mission)
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TDS	Theater Defense Systems
TIMED	Thermosphere-Ionosphere-Mesosphere Energetics & Dynamics
TMD	Theater Missile Defense
TOMS	Total Ozone Mapping Spectrometer
TOPS	Toward Other Planetary Systems (Program)
TPIPT	(USAF) Technology Planning Integrated Product Team
TRACE	Transitional Region and Coronal Explorer
TSS	Tethered Satellite System
TSTO	Two Stage to Orbit (HRV)
UFO	Ultra-High Frequency (UHF) Follow-On
UNEX	University-Class Explorer (Missions)
USAF	US Air Force
USML	US Microgravity Laboratory

USMP	US Microgravity Payload (Missions)
USN	US Navy
WIRE	Wide-Field IR Explorer

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Appendices

The following are appendices with supporting information, including references and participants for the NFS space mission and requirements modeling effort, details of the U.S. launch projection, and the NFS Terms of Reference document.

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Appendix A

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Appendix B
Participants

The following is a list of names and organizations of the individuals who contributed to the mission and requirements model, and launch projections.

Darrell Branscome (co-Lead, Space Operations requirements team)
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National Aeronautics and Space Administration

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USAF/Phillips Laboratory
Department of Defense

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Advanced Concepts Division
Office of Advanced Concepts and Technology
National Aeronautics and Space Administration

Rick Reynolds, Lt. Colonel, USAF (co-Lead, Space Operations requirements team)
AFSPACECOM
Department of Defense

W. Kyle Sneddon, Captain, USAF (Executive Secretary, Space R&D requirements team)
USAF, Phillips Laboratory
Department of Defense

Michael D. Abrams, Commander, USN
Naval Research Laboratory
Department of Defense

Frederick E. Betz
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Department of Defense

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Office of Space Systems Development
National Aeronautics and Space Administration

Joe Foreman
Naval Research Laboratory
Department of Defense

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Department of Commerce

Donald Palac
Lewis Research Center
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Karen Poniatowski
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Department of Commerce

Appendix C

NFS Terms of Reference

1. BACKGROUND

The United States is increasingly challenged by advances in technologies that will affect its global competitiveness in virtually all economic sectors. Preeminent among these are advances in aerospace technology. These advances are paced by modern highly productive research, development, and operational facilities. Recognizing this situation, on November 13, 1992, the NASA Administrator initiated the development of a comprehensive and integrated long-term plan for future aerospace facilities. This integrated plan would be accomplished in partnership with other Government agencies, industry, and academia to ensure that the facilities are world-class and to avoid duplication of effort. He contacted top officials in the Departments of Defense, Energy, Transportation, Commerce, and the National Science foundation inviting them to participate in the development of the plan and the appropriate working groups. The Administrator proposed an Oversight Group chaired by John R. Dailey, NASA Associate Deputy Administrator, with representation from DoD, DOT, DOE, DOC, and the NSF. Each of the agencies responded with nominations of individuals to serve on the Oversight Group and provide support on Task Groups to establish detailed plans. This Terms of Reference document provides the coordinated charter for development of the Aerospace Facilities Plan.

2. PURPOSE

To formulate a coordinated Nation Plan for world-class aeronautical and space facilities that meets the current and projected needs for commercial and Government research and development, and for Government and commercial space operations.

3. SCOPE

The plan will include a catalog of existing Government and industry facilities that support aeronautics and astronautics research, development, testing, and operations. International facilities will also be cataloged to determine capability relative to U.S. facilities and applicability to address U.S. facility shortfalls.

The plan will include a requirements analysis which will consider current and future Government and commercial industry needs as well as DoD and NASA mission requirements, through the year 2023, and specifically will address shortfalls in existing capabilities, new facility requirements, upgrades, consolidation, and phase out of existing facilities. All new facility requirements and upgrades will be prioritized and detailed schedules and total funding will be specified.

Joint management schemes, life cycle costs, and siting requirements will be fully evaluated.

Joint funding between agencies and Government/industry will be considered. Shared usage policies will be developed where nonexistent.

Costing, definitions, evaluation methodology and dollar threshold for facility inclusion in review will be approved by the Oversight Group.

4. ORGANIZATION

An Oversight Group, chaired by NASA with a DoD Vice-Chairman and including membership from DOE, DOT, DOC and the National Science Foundation, will have responsibility for implementing this TOR and plan development. The secretary will be nominated by NASA.

The chairman will appoint a study director for executing this TOR. This person will be responsible for conducting the study and its schedule, coordinating participation, integrating all inputs, preparing the final products, and providing those products to the Oversight Group.

To assist the study director, four task groups will be established. These are the Aeronautics R&D Task Group, the Space R&D Task Group, the Space Operations Task Group and the Facilities Costing and Engineering Group. The task groups will be co-chaired by NASA and DOC. All participating agencies will provide representatives to each task group. The task groups will have the authority to establish working groups to assist them in their tasks. Membership on the task and working groups will be limited to Government employees and participation is optional, except for NASA and DoD. The Aeronautics Task Group is an exception because of the special need to address commercial transport aircraft. For this reason experts from private industry participate as Special Government Employees, and the task group will function in accordance with the Federal Advisory Committee Act. Throughout the study, however, industry and academic inputs and advice should be actively solicited.

The Oversight Group will provide guidance to the task groups, serve as the coordination mechanism, perform periodic progress reviews, resolve disputes or misunderstandings that may arise between the agencies under the memorandum, and recommend an integrated plan for agency approval. The task groups will have responsibility for planning, directing, and providing recommendations in their particular discipline area.

Each agency will utilize its own reporting and tasking authority and will bear its and its employees' own costs for participation. Activities shall be subject to the availability of funds and personnel of each party.

5. PRODUCT

The study director will provide a summary report to the Oversight Group incorporating input from each of the task groups that includes a compendium of current facilities and capabilities: identification of shortfalls as a function of current and projected needs; and recommendations and rationale for new facilities, upgrades, consolidation, or closure of existing facilities. Recommendations will include cost impacts, either as investment costs or savings, and any other considerations that would bear on the decision (i.e., national security concerns, technology transfer, proprietary data rights, commercial competitiveness, etc.). The summary report will also include any recommendations relative to a policy nature, such as shared usage, common costing, and management and operation.

Upon approval by the Oversight Group, each report will be forwarded for agency approval. Final reports will be approved at the Deputy Administrator/Under Secretary level or equivalent. For the DoD the responsible authority is the Under Secretary of Defense for Acquisition. Final reports should reflect a national viewpoint endorsed by NASA, DoD, DOC, DOT, DOE and NSF.

6. SCHEDULE

Interim Task Group Reports (to support FY 195 budget decisions)	July 1993
Final Task Group Reports	January 1994
Oversight Approval - Task Group Reports	February 1994
Coordination of Individual Reports	March 1994
Approval of Individual Reports	March 1994

7. APPROVAL, AMENDMENT, AND TERMINATION

This Terms of Reference shall enter into force upon the signature of all Parties and shall remain in force through July 1994. It may be modified, extended, or terminated by mutual consent of all parties.

Original Approved by:

Department of Commerce, David Barram, Deputy Secretary
Department of Defense, William J. Perry, Deputy Secretary
Department of Energy, Bill White, Deputy Secretary
Department of Transportation, Mortimer L. Downey, Deputy Secretary
National Aeronautics and Space Administration, Daniel S. Goldin, Administrator
National Science Foundation, Neal Lane, Director

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Appendix D

U.S. Launch Projection Details

The following appendix provides details concerning the U.S. launch model projection used for the NFS.

Projected Launch Vehicle Traffic by Payload Class

Current U.S. Launch Rate Capability

	Eastern Test Range	Western Test Range
• Space Shuttle	LC-39A & B 8/yr	
• Titan IV	LC-40 2/yr LC-41 2/yr	SLC-4E 2/yr
• Titan II (Actual T-II capacity may be decreased by T-IV activities)		SLC-4W 3/yr
• Atlas	LC-36A 4/yr LC-36B 5/yr (combined 9/yr total)	SLC-3E 4/yr
• Delta	LC-17A + LC-17B + SLC-2W = 10/yr (ETR and WTR Combined, Note Delta Launch Crew Dependency)	
• Pegasus	No capacity constraints except range conflicts	
• Taurus		576E 12/yr

Data Provided by HQ AFSPACECOM, Launch Services Office; May 27, 1993, Capt D. Hollenbach
Sources: 30th SPW/XPR, XPR 10-Year Schedule Extrapolation
45th SPW/CV, 45th SPW/XPR Launch Forecast
BMDO Test & Experiments Activities Summary Extrapolation

Suborbital Launch Rates

• **NASA Suborbital Science Program**	
• **Wallops**	**5/yr**
• **White Sands**	**14/yr**
• **Poker Flats Research Range**	**6/yr**
• **Foreign Campaigns (Non-U.S. Launch Sites)**	**5/yr**
• **Commercial**	
• **Western Test Range/VAFB (HyFlyer)**	**1/yr**
• **DoD**	
• **Western Test Range**	
- **VAFB (Peacekeeper/Minuteman, Military)**	**7/yr**
- **VAFB (Minuteman I/II, R&D)**	**3/yr**
- **VAFB (Other Independent Experiments, University)**	**3/yr**
- **VAFB Range Support (Submarine Launch)**	**3/yr**
- **Kwajalein (BDMO R&D)**	**5/yr**
- **Kauai Test Facility**	**2/yr**
• **Eastern Test Range**	
- **CCAFS SLC-20 (R&D)**	**1/yr**
- **CCAFS Range Support (Submarine Launch)**	**4/yr**
- **Wallops (BDMO R&D)**	**2/yr**
• **White Sands (R&D)**	**5/yr**

Notes:
DoD Data Provided by HQ AFSPACECOM, Launch Services Office; June 10, 1993, Capt D. Hollenbach
NASA Data Provided by OSS Flight Programs Office; July 13, 1993, P. DeMinco

Total Traffic Projection
(Combined NASA, DoD, and Commercial)

Total Traffic Projection
9/20/1993 Version

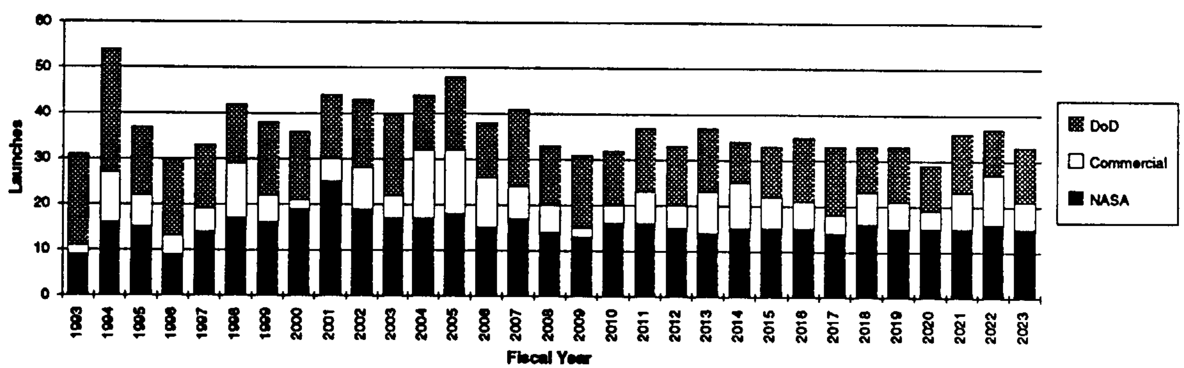
For Planning Purposes ONLY

Total Traffic by User

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
NASA	9	16	15	9	14	17	16	19	25	19	17	17	18	15	17	14
Commercial	2	11	7	4	5	12	6	2	5	9	5	15	14	11	7	6
DoD	20	27	15	17	14	13	16	15	14	15	18	12	16	12	17	13
TOTAL	31	54	37	30	33	42	38	36	44	43	40	44	48	38	41	33

(FY)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Change
NASA	13	16	16	15	14	15	15	15	14	16	15	15	15	16	15	482
Commercial	2	4	7	5	9	10	7	6	4	7	6	4	8	11	6	217
DoD	16	12	14	13	14	9	11	14	15	10	12	10	13	10	12	439
TOTAL	31	32	37	33	37	34	33	35	33	33	33	29	36	37	33	1138

Total Traffic Projection by User



NASA Notes:
1. Last report dated: 8/16/93, R. Brodowski, Code DN, 202-358-4494
2. NASA model from 1993 to 2010 based on Memo: "NASA ELV Manifest and Long Range Planning Status", Code SV, August 17, 1993, K. Poniatowski
3. Data from 2011 to 2020 extrapolated as a function of mission category
4. Shuttle flight rate data from 1993 to 1996 based on "SSP Internal Baseline Manifest-April 29, 1993," signed Thomas E. Utsman; includes DoD missions; flight rate from 1996 to 2023 assumes nominal 8 flights per year

DoD Notes:
2. DoD model FY93-20 provided by HQ AFSPACECOM, Launch Services Office; FAX "Traffic Rate Projection," September 20, 1993, Capt D. Hollenbach

Commercial Notes:
2. Commercial model from 1993 to 1996 based on Memo: "NASA ELV Manifest and Long Range Planning Status", Code SV, August 17, 1993, K. Poniatowski
3. Commercial traffic from 1997 to 2010 provided by Office of Commercial Space Transportation/DoT, FAX dated Sept. 17, 1993; U.S. launches assume 40% capture of total international market
4. Commercial model from 2011 to 2023 average of projected flight rates from 1993 to 2010

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Total Traffic Projection
9/20/1993 Version

ΔTotal Traffic 9/20-1/5 Mod

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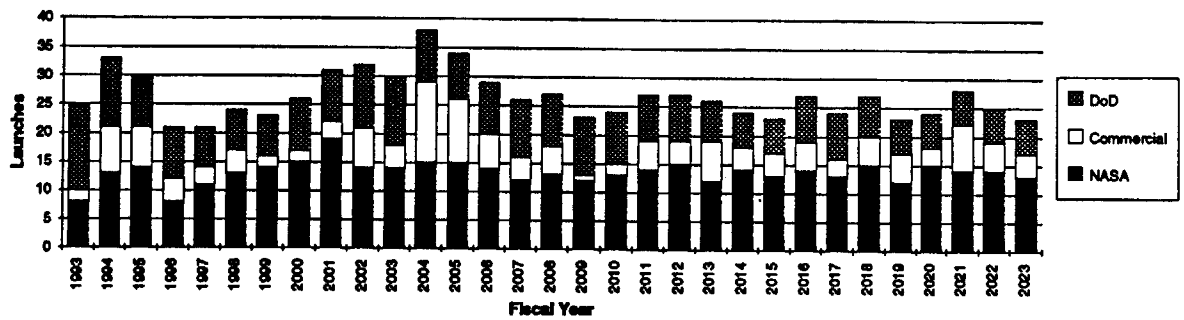
East Coast Traffic by User

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Change
NASA	8	13	14	8	11	13	14	15	19	14	14	15	15	14	12	13	12	13	14	15	12	14	13	14	13	15	12	15	14	14	13	415
Commercial	2	8	7	4	3	4	2	2	3	7	4	14	11	6	4	5	1	2	5	4	7	4	4	5	3	5	5	3	8	5	4	151
DoD	15	12	9	9	7	7	7	9	9	11	12	9	8	9	10	9	10	9	8	8	7	6	6	8	8	7	6	6	6	6	6	259
East Coast TOTAL	25	33	30	21	21	24	23	26	31	32	30	38	34	29	26	27	23	24	27	27	26	24	23	27	24	27	23	24	28	25	23	825

East Coast Traffic Projection by User



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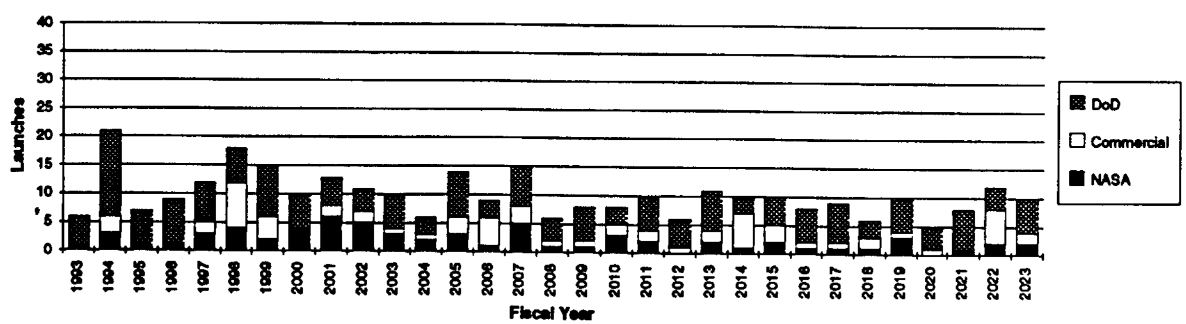
West Coast Traffic by User

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Change
NASA	1	3	1	1	3	4	2	4	6	5	3	2	3	1	5	1	1	3	2	0	2	1	2	1	1	1	3	0	1	2	2	67
Commercial	0	3	0	0	2	8	4	0	2	2	1	1	3	5	3	1	1	2	2	1	2	6	3	1	1	2	1	1	0	6	2	66
DoD	5	15	6	8	7	6	9	6	5	4	6	3	8	3	7	4	6	3	6	5	7	3	5	6	7	3	6	4	7	4	6	180
West Coast TOTAL	6	21	7	9	12	18	15	10	13	11	10	6	14	9	15	6	8	8	10	6	11	10	10	8	9	6	10	5	8	12	10	313

West Coast Traffic Projection by User

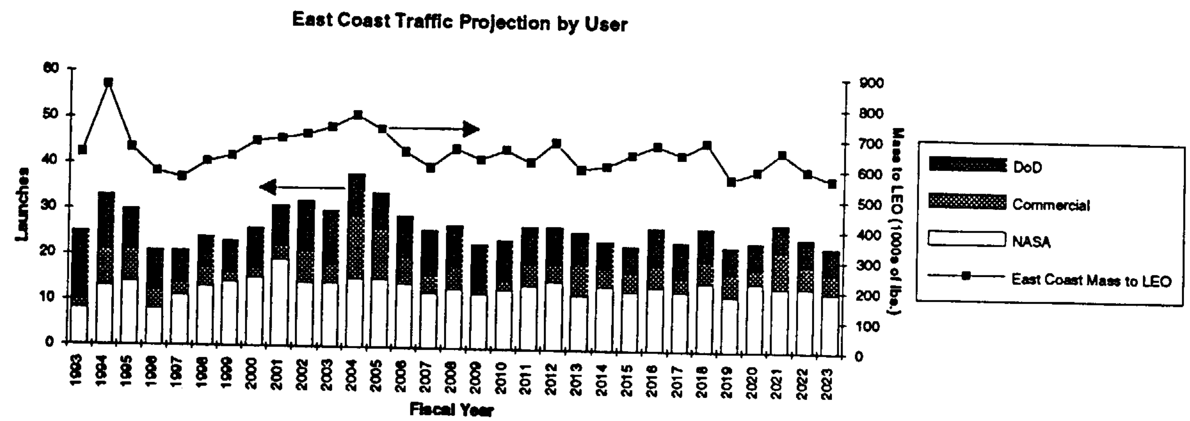


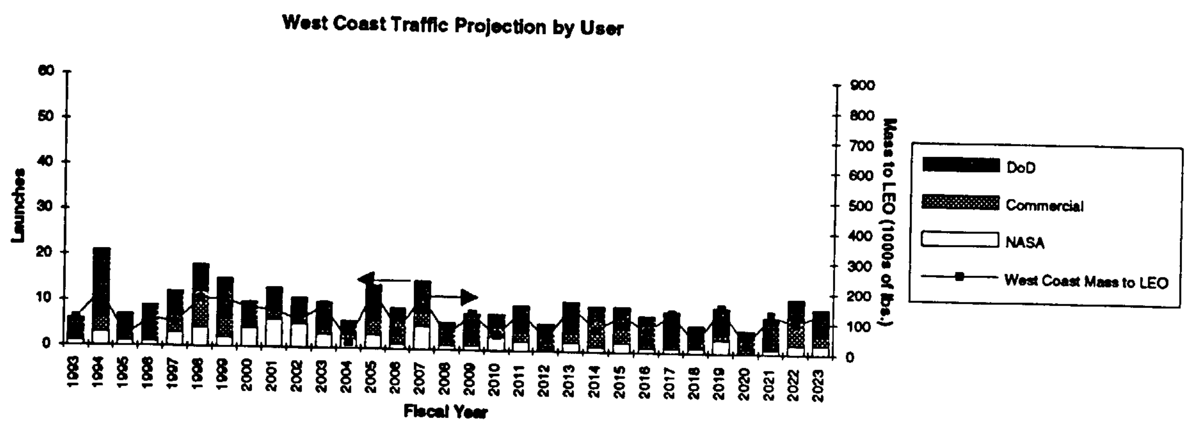
TOTAL	31	54	37	30	33	42	38	36	44	43	40	44	48	38	41	33	31	32	37	33	37	34	33	35	33	33	33	29	36	37	33	1138

For Planning Purposes ONLY

Total Traffic Projection
9/20/1993 Version

For Planning Purposes ONLY





For Planning Purposes ONLY

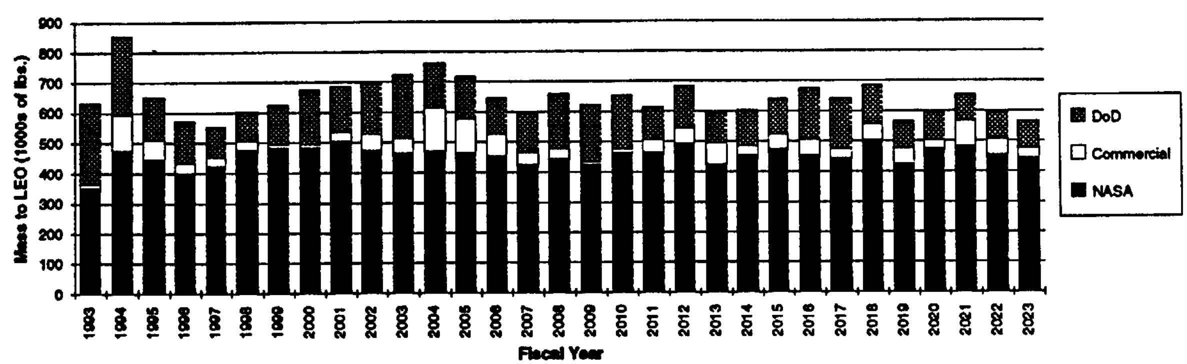
Total Traffic Projection
9/20/1993 Version

ΔTotal Traffic 9/20-1/5 Mod

For Planning Purposes ONLY

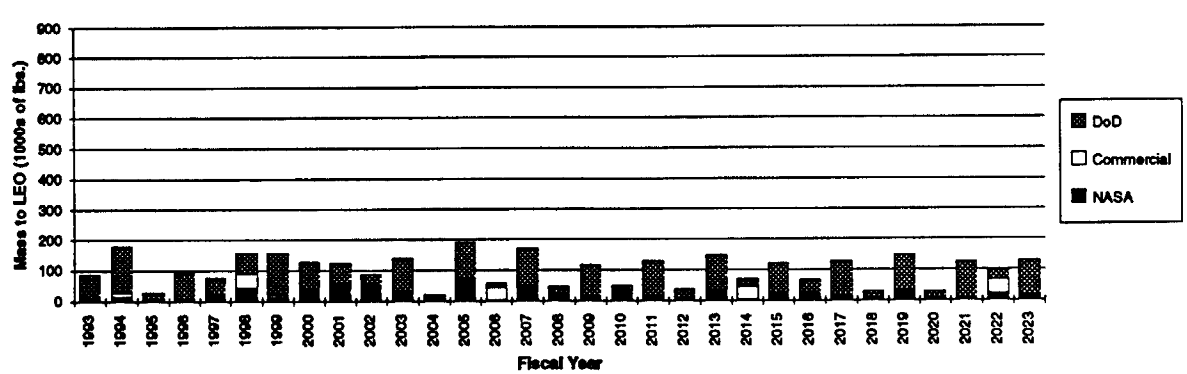
East Coast: Mass to LEO by User

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Change
NASA	352	474	446	400	422	474	484	484	504	474	464	472	466	454	424	444	424	464	464	494	424	454	474	454	444	504	424	474	484	454	444	14118
Commercial	12	120	64	32	32	32	12	12	32	56	50	142	112	72	42	34	10	12	42	50	72	32	50	52	30	52	52	30	82	52	32	1506
DoD	270	262	142	142	100	100	130	180	150	170	210	150	140	120	130	180	190	180	110	140	100	120	120	170	170	130	90	90	90	90	90	4456
East Coast Mass to LEO	634	856	652	574	554	606	626	676	686	700	724	764	718	646	596	658	624	656	616	684	596	606	644	676	644	686	566	594	656	596	566	20080



West Coast: Mass to LEO by User

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Change
NASA	2	14	10	2	22	42	12	42	54	50	32	12	70	2	42	20	10	32	12	0	30	2	12	20	10	2	32	0	10	22	12	634
Commercial	0	14	0	0	4	48	8	0	4	4	2	2	6	42	6	2	2	4	4	2	4	44	6	2	2	4	2	2	0	44	4	268
DoD	86	152	20	92	52	68	138	86	66	34	106	6	118	14	124	26	106	14	114	36	116	24	104	46	116	24	114	26	116	34	114	2292
West Coast Mass to LEO	88	180	30	94	78	158	158	128	124	88	140	20	194	58	172	48	118	50	130	38	150	70	122	68	128	30	148	28	126	100	130	3194



Total Mass to LEO	722	1036	682	668	632	764	784	804	810	788	864	784	912	704	768	706	742	706	746	722	746	676	766	744	772	716	714	622	782	696	696	23274

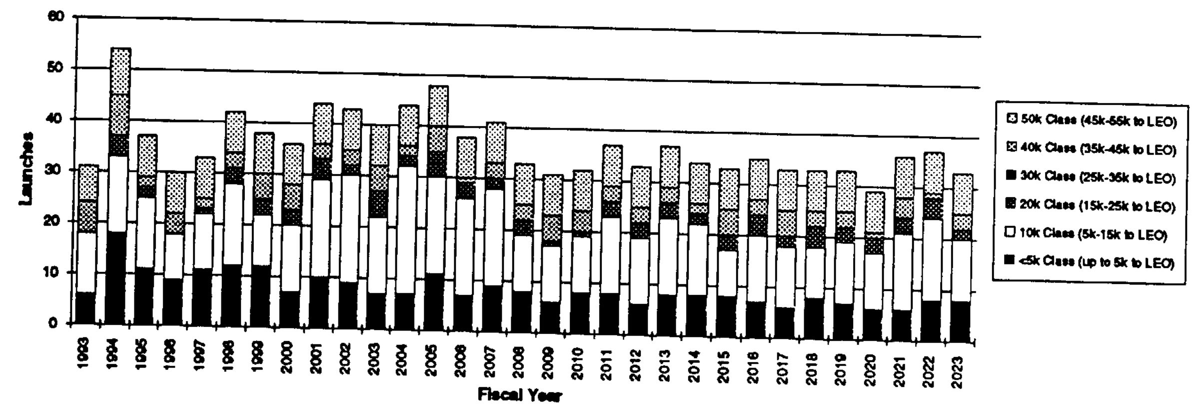
Total Traffic Projection
9/20/1993 Version

For Planning Purposes ONLY
Vehicle Selection Is Notional and Does NOT Imply Contracting Decisions

Total Traffic Projection

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023		Change
<5k Class (up to 5k to LEO)	6	18	11	9	11	12	12	7	10	9	7	7	11	7	9	8	6	8	8	6	8	8	8	7	6	8	7	6	6	8	8	262	√
10k Class (5k-15k to LEO)	12	15	14	9	11	16	10	13	19	21	15	25	19	19	19	11	11	11	15	13	15	14	9	13	12	10	12	11	15	16	12	437	√
20k Class (15k-25k to LEO)	0	4	2	0	1	3	3	3	4	2	5	2	5	3	2	3	1	1	3	3	3	2	3	4	2	4	3	3	3	4	2	83	
30k Class (25k-35k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	√
40k Class (35k-45k to LEO)	6	8	2	4	2	3	5	5	3	3	5	2	5	1	3	3	5	4	3	3	3	2	5	3	5	3	3	1	4	1	3	108	
50k Class (45k-55k to LEO)	7	9	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	248	√
	31	54	37	30	33	42	38	36	44	43	40	44	48	38	41	33	31	32	37	33	37	34	33	35	33	33	33	29	36	37	33	1138	√

Total Traffic Projection by Vehicle



NASA Notes:
1. Last report dated: 8/16/93, R. Brodowski, Code DN, 202-358-4494
2. NASA model from 1993 to 2010 based on Memo: "NASA ELV Manifest and Long Range Planning Status", Code SV, August 17, 1993, K. Poniatowski
3. Data from 2011 to 2020 extrapolated as a function of mission category
4. Shuttle flight rate data from 1993 to 1996 based on "SSP Internal Baseline Manifest-April 29, 1993," signed Thomas E. Utsman; includes DoD missions; flight rate from 1996 to 2023 assumes nominal 8 flights per year

DoD Notes:
2. DoD model FY93-20 provided by HQ AFSPACECOM, Launch Services Office; FAX "Traffic Rate Projection," September 20, 1993, Capt D. Hollenbach

Commercial Notes:
2. Commercial model from 1993 to 1996 based on Memo: "NASA ELV Manifest and Long Range Planning Status", Code SV, August 17, 1993, K. Poniatowski
3. Commercial traffic from 1997 to 2010 provided by Office of Commercial Space Transportation/DoT, FAX dated Sept. 17, 1993; U.S. launches assume 40% capture of total international market
4. Commercial model from 2011 to 2023 average of projected flight rates from 1993 to 2010

For Planning Purposes ONLY
Vehicle Selection Is Notional and Does NOT Imply Contracting Decisions

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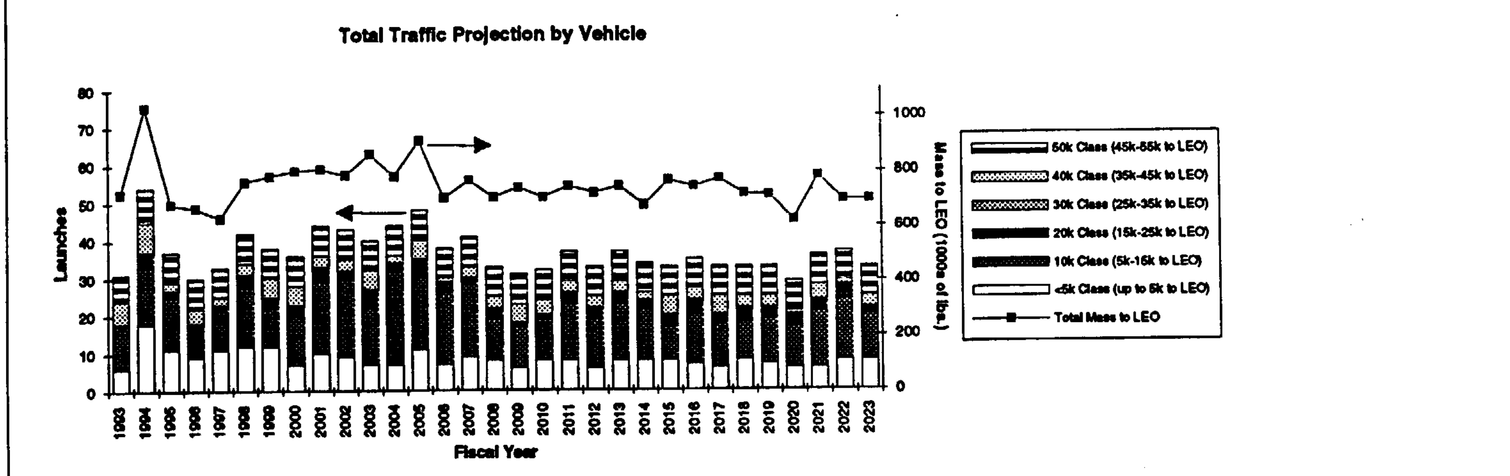
Total Traffic Projection
9/20/1993 Version

For Planning Purposes ONLY
Vehicle Selection Is Notional and Does NOT Imply Contracting Decisions



NASA Notes:

1. Last report dated: 8/16/93, R. Brodowski, Code DN, 202-358-4494
2. NASA model from 1993 to 2010 based on Memo: "NASA ELV Manifest and Long Range Planning Status", Code SV, August 17, 1993, K. Poniatowski
3. Data from 2011 to 2020 extrapolated as a function of mission category
4. Shuttle flight rate data from 1993 to 1996 based on "SSP Internal Baseline Manifest-April 29, 1993," signed Thomas E. Utsman; includes DoD missions; flight rate from 1996 to 2023 assumes nominal 8 flights per year

DoD Notes:

2. DoD model FY93-20 provided by HQ AFSPACECOM, Launch Services Office; FAX "Traffic Rate Projection," September 20, 1993, Capt D. Hollenbach

Commercial Notes:

2. Commercial model from 1993 to 1996 based on Memo: "NASA ELV Manifest and Long Range Planning Status", Code SV, August 17, 1993, K. Poniatowski
3. Commercial traffic from 1997 to 2010 provided by Office of Commercial Space Transportation/DoT, FAX dated Sept. 17, 1993; U.S. launches assume 40% capture of total international market

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Vehicle Selection Is Notional and Does NOT Imply Contracting Decisions

Total Traffic Projection
9/20/1993 Version

For Planning Purposes ONLY
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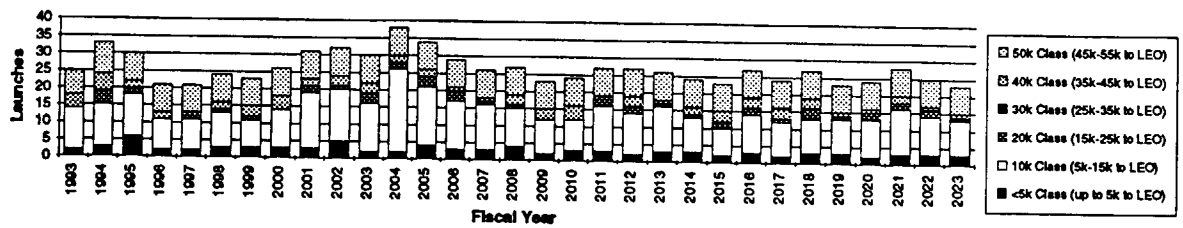
East Coast (KSC, CCAFS) Launches

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023		Change
<5k Class (up to 5k to LEO)	2	3	6	2	2	3	3	3	3	5	2	2	4	3	3	4	2	3	3	2	3	3	2	3	2	3	3	2	3	3	3	90	√
10k Class (5k-15k to LEO)	12	12	12	9	9	10	8	11	16	15	14	24	17	14	13	11	10	9	13	12	13	10	8	11	10	10	10	11	13	11	10	368	√
20k Class (15k-25k to LEO)	0	4	2	0	1	1	1	0	2	1	3	2	3	3	1	1	0	0	2	2	1	1	2	2	1	3	1	2	2	2	1	47	
30k Class (25k-35k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	√
40k Class (35k-45k to LEO)	4	5	2	2	1	2	3	4	2	3	3	2	2	1	1	3	3	4	1	3	1	2	3	3	3	3	1	1	2	1	1	72	
50k Class (45k-55k to LEO)	7	9	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	248	√
	25	33	30	21	21	24	23	26	31	32	30	38	34	29	26	27	23	24	27	27	26	24	23	27	24	27	23	24	28	25	23	825	√

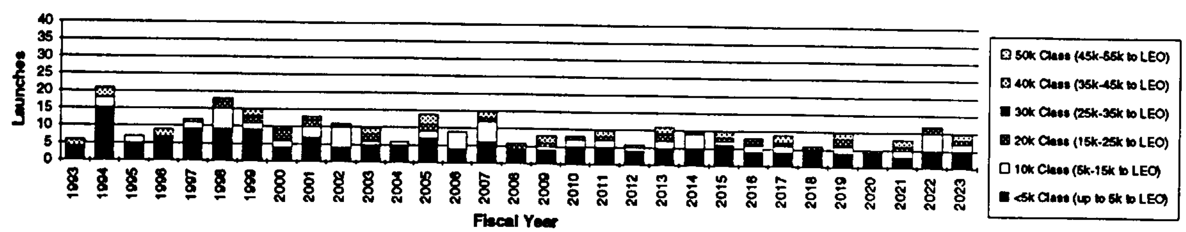
East Coast Traffic Projection by Vehicle



West Coast (VAFB) Launches

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023		
<5k Class (up to 5k to LEO)	4	15	5	7	9	9	9	4	7	4	5	5	7	4	6	4	4	5	5	4	5	5	6	4	4	5	4	4	3	5	5	172	
10k Class (5k-15k to LEO)	0	3	2	0	2	6	2	2	3	6	1	1	2	5	6	0	1	2	2	1	2	4	1	2	2	0	2	0	2	5	2	69	√
20k Class (15k-25k to LEO)	0	0	0	0	0	2	2	3	2	1	2	0	2	0	1	2	1	1	1	1	2	1	1	2	1	1	2	1	1	2	1	36	
30k Class (25k-35k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
40k Class (35k-45k to LEO)	2	3	0	2	1	1	2	1	1	0	2	0	3	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	36	
50k Class (45k-55k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	6	21	7	9	12	18	15	10	13	11	10	6	14	9	15	6	8	8	10	6	11	10	10	8	9	6	10	5	8	12	10	313	√

West Coast Traffic Projection by Vehicle



Total Launches

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023		
	31	54	37	30	33	42	38	36	44	43	40	44	48	38	41	33	31	32	37	33	37	34	33	35	33	33	33	29	36	37	33	1138	√

NASA Notes:
1. Last report dated: 8/16/93, R. Brodowski, Code DN, 202-358-4494
2. NASA model from 1993 to 2010 based on Memo: "NASA ELV Manifest and Long Range Planning Status", Code SV, August 17, 1993, K. Poniatowski
3. Data from 2011 to 2020 extrapolated as a function of mission category
4. Shuttle flight rate data from 1993 to 1996 based on "SSP Internal Baseline Manifest-April 29, 1993," signed Thomas E. Utsman; includes DoD missions; flight rate from 1996 to 2023 assumes nominal 8 flights per year

DoD Notes:
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Commercial Notes:
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3. Commercial traffic from 1997 to 2010 provided by Office of Commercial Space Transportation/DoT, FAX dated Sept. 17, 1993; U.S. launches assume 40% capture of total international market
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NASA Traffic Projection

NASA Traffic Projection
9/20/1993 Version

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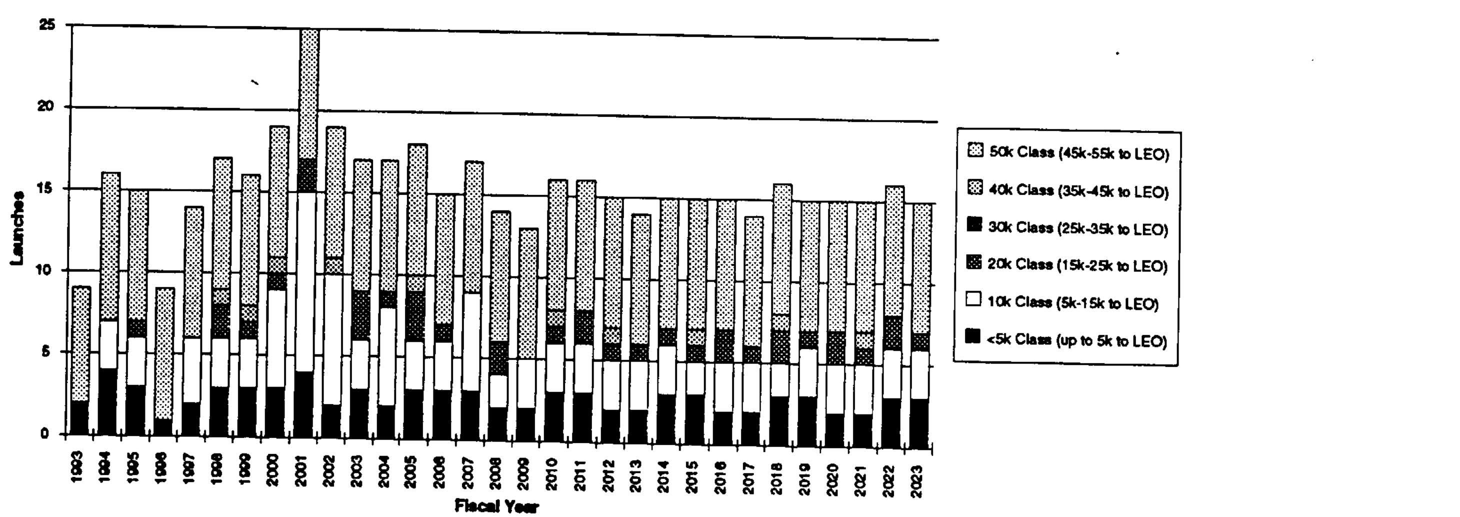
NASA Traffic

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
<5k Class (up to 5k to LEO)	2	4	3	1	2	3	3	3	4	2	3	2	3	3	3	2
10k Class (5k-15k to LEO)	0	3	3	0	4	3	3	6	11	8	3	6	3	3	6	2
20k Class (15k-25k to LEO)	0	0	1	0	0	2	1	1	2	0	3	1	3	1	0	2
30k Class (25k-35k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40k Class (35k-45k to LEO)	0	0	0	0	0	1	1	1	0	1	0	0	1	0	0	0
50k Class (45k-55k to LEO)	7	9	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	9	16	15	9	14	17	16	19	25	19	17	17	18	15	17	14

(FY)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Totals	Change
<5k Class (up to 5k to LEO)	2	3	3	2	2	3	3	2	2	3	3	2	2	3	3	81	
10k Class (5k-15k to LEO)	3	3	3	3	3	3	2	3	3	2	3	3	3	3	3	107	
20k Class (15k-25k to LEO)	0	1	2	1	1	1	1	2	1	2	1	2	1	2	1	36	
30k Class (25k-35k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
40k Class (35k-45k to LEO)	0	1	0	1	0	0	1	0	0	1	0	0	1	0	0	10	
50k Class (45k-55k to LEO)	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	248	
	13	16	16	15	14	15	15	15	14	16	15	15	15	16	15	482	

NASA Traffic Projection



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9/20/1993 Version

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East Coast (KSC, CCAFS) Launches

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Totals	Change
<5k Class (up to 5k to LEO)	1	2	3	0	1	2	2	2	2	2	2	1	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	59	
10k Class (5k-15k to LEO)	0	2	2	0	2	1	2	4	8	3	2	5	2	3	2	2	2	2	2	3	2	3	1	3	2	2	2	3	2	3	2	74	
20k Class (15k-25k to LEO)	0	0	1	0	0	1	1	0	1	0	2	1	2	1	0	1	0	0	2	1	0	1	1	1	1	2	0	2	1	1	1	25	
30k Class (25k-35k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
40k Class (35k-45k to LEO)	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	1	0	0	1	0	0	9	
50k Class (45k-55k to LEO)	7	9	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	248	
	8	13	14	8	11	13	14	15	19	14	14	15	15	14	12	13	12	13	14	15	12	14	13	14	13	15	12	15	14	14	13	415	
Mass to LEO	352	474	446	400	422	474	484	484	504	474	464	472	466	454	424	444	424	464	464	494	424	454	474	454	444	504	424	474	484	454	444		

West Coast (VAFB) Launches

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Totals
<5k Class (up to 5k to LEO)	1	2	0	1	1	1	1	1	2	0	1	1	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	22
10k Class (5k-15k to LEO)	0	1	1	0	2	2	1	2	3	5	1	1	1	0	4	0	1	1	1	0	1	0	1	0	1	0	1	0	1	0	1	33
20k Class (15k-25k to LEO)	0	0	0	0	0	1	0	1	1	0	1	0	1	0	0	1	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	11
30k Class (25k-35k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40k Class (35k-45k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
50k Class (45k-55k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	3	1	1	3	4	2	4	6	5	3	2	3	1	5	1	1	3	2	0	2	1	2	1	1	1	3	0	1	2	2	67
Mass to LEO	2	14	10	2	22	42	12	42	54	50	32	12	70	2	42	20	10	32	12	0	30	2	12	20	10	2	32	0	10	22	12	

Total Launches

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Totals
	9	16	15	9	14	17	16	19	25	19	17	17	18	15	17	14	13	16	16	15	14	15	15	15	14	16	15	15	15	16	15	482

Notes:
1. Last report dated: 8/16/93, R. Brodowski, Code DN, 202-358-4494
2. NASA model from 1993 to 2010 based on Memo: "NASA ELV Manifest and Long Range Planning Status", Code SV, August 17, 1993, K. Poniatowski
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NAME	FY	Date	KP List	Site	Class		MASS TO LEO	PLD MASS	DEST	APO	PER	INC	DELTA V	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	Total	11	12	13	14	15	16	17	18	19	20	21	22	23	Total	Change
COMET	1993	Aug-93	Conestoga	WFF	SC	Planned								1	1	1																3														0	
TOMS	1994	May-94	Pegasus	WFF	SC	Planned									1																	1														0	√
FAST	1994	Aug-94	Pegasus	VAFB	SC	Planned									1																	1														0	
SAC-B/HETE	1995	Apr-95	Pegasus	WFF	SC	Planned										1																1														0	
SWAS	1995	Jun-95	Pegasus	WFF	SC	Planned										1																1														0	
SMEX	1997	Jun-97	Pegasus	WFF	SC	Planned												1	1	1	1	1	1	1	1	1	1	1	1	1	1	14														0	
OAMES	1998			VAFB	SC	Potential													1													1														0	√
UNEX	1998				SC	Potential													1	1	1	1	1	1	1	1	1	1	1	1	1	13														0	
AERO	2000	Sep-00	Pegasus	VAFB	SC	Planned															1			1			1					3														0	
HESP	2001			WFF/V/	SC	Potential			EAR OTH	324	324	90.0	26267									2										2														0	√
PROBE	2005				SC	Potential																				1		1			1	3														0	
GENERICSC	2011				SC	Extrapolated																										0	3	2	2	3	3	2	2	3	3	2	2	3	3	33	
														1	3	3	0	1	3	2	3	4	2	3	2	3	3	3	2	2	3	43	3	2	2	3	3	2	2	3	3	2	2	3	3	33	√

NAME	FY	Date	KP List	Site	Class		MASS TO LEO	PLD MASS	DEST	APO	PER	INC	DELTA V	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	Total	11	12	13	14	15	16	17	18	19	20	21	22	23	Total	Change
NOAA	1993	Aug-93	Atlas/TII	West	MC	Planned	2883	2255	LEO SYN	460	460	98.7	26702	1	1		1	1		1	1		1		1			1			1	10														0	√
WIND	1994	Apr-94	Delta	East	MC	Planned	9956	2645	LUN ORB	826560	41328	0.0	34768		1																	1														0	√
POLAR	1994	Jun-94	Delta	West	MC	Planned	10119	2645	EAR OTH	30986	6199	90.0	36255		1																	1														0	√
RADARSAT	1995	Dec-94	Delta	West	MC	Planned	8167	7040	LEO SYN	411	411	98.5	26548			1																1														0	
XTE	1995	Aug-95	Delta	East	MC	Planned	7209	6505	LEO OTH	270	270	28.5	24748			1																1														0	
SCOUT				East	MC		4585	1200	LUN ORB	-	-	-	34768				0	0														0														0	√
LAGEOS-III	1997		MC	West	MC	Potential	2424	893	LEO OTH	3240	3240	52.0	30940					1														1														0	√
MESUR	1997	Nov-96	Delta	East	MC	Planned	4941	1316	DS MAR SUR	-	-	-	34768					1		0		2										3														0	√
ACE	1997	Aug-97	Delta	East	MC	Planned	7123	1433	EAR OTH	826543	826543	0.0	36228					1														1														0	
RANGER	1997			West	MC	Potential												1														1														0	√
NEAR	1998	Jan-96	Delta	East	MC	Planned	5710	1566	DS C/A	-	-	-	34768				0		1													1														0	√
ARISTOTELES	1998		MC	West	MC	Potential	5443	4840	LEO POL	270	270	95.0	26088						1													1														0	
LANDSAT 7	1998		MC	West	MC	Potential													1													1														0	
AXAF-S	2000	Dec-99	Delta	West	MC	Planned	8628	7400	LEO OTH	320	320	28.5	26614							0	1											1														0	√
TIMED H,L	1999		MC	E/W	MC	Potential	11217	2750	LEO SYN	3238	81	0.0	35463							2												2														0	
EOS/SAR	2000		MC	West	MC	Potential	3426	2867	LEO SYN	335	335	97.5	26303								1											1														0	
DISCOVERY	2000		MC	East	MC	Potential															1	1	1	1	1	1	1	1	1	1	1	11														0	√
MI	2002		MC	West	MC	Potential	5185	1870	EAR OTH	20683	216	90.0	33772								0		1									1														0	
MIDEX	2000		MC	E/W	MC	Potential	3000	3000	LEO OTH				26700*								1	1	1	1	1	1	1	1	1	1	1	11														0	
FUSE	2001	Dec-00	MC	East	MC	Planned	2867	2867	LEO OTH				26500*									1										1														0	
GPB	2001	Dec-00	MC	West	MC	Planned																1										1														0	
GTC	2001		MC	East	C	Potential	9856	9856	EAR OTH			90.0	35000*									1										1														0	√
LUNAR SCOUT	2001		MC	East	MC	Potential	7885	2000	LUN ORB	-	-		34768									1										1														0	
PROBE (M)	2001		MC	East	MC	Potential	7000	7000	EAR OTH				26700*									1		1		1		1		1		5														0	
SMM	2001		MC	East	MC	Potential	6135	2000	LEO SYN	37797	540	90.0	34806									1										1														0	
ALT	2002		MC	West	MC	Potential	6000	6000	LEO OTH				26700*										1					1				2														0	
OSL	2002		MC	West	MC	Potential	4361	3813	LEO SYN	275	275	97.4	26104										1									1														0	
AIM	2004		MC	East	MC	Potential							26700*												1							1														0	
GENERIC EO-1	2011		MC		MC	Extrapolated	10943	2400	EAR OTH	31000	6000	90.0	36250																			0	1		1		1		1		1		1		1	7	
GENERIC LEO OTH-1	2011		MC		MC	Extrapolated	3000	3000	LEO OTH	270	270	28.5	24800																			0	1	1	1	1	1	1	1	1		1	1	1	1	12	
GENERIC LEO SYN	2011		MC		MC	Extrapolated	11462	3000	LEO SYN	450	450	90.0	35000																			0	1	1	1	1		1	1	1	1	1	1	1	1	12	
GENERIC DS-1	2013		MC		MC	Extrapolated	5815	1600	DS Planetary	-	-	-	34768																			0		1				1				1		1		4	
GENERIC LUN-1	2014		MC		MC	Extrapolated	10132	2700	LUNAR	-	-	-	34768																			0				1					1					2	
														1	3	2	1	5	3	3	5	10	6	3	4	3	2	5	2	3	3	64	3	3	3	3	2	3	3	2	3	3	3	3	3	37	

NAME	FY						MASS TO LEO	PLD MASS	DEST	APO	PER	INC	DELTA V	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	Total	11	12	13	14	15	16	17	18	19	20	21	22	23	Total	Change
GOES	1994	Apr-94	Atlas I/IC	East	IC	Planned	16470	2160	GEO	19310	19310	0.0	38267		1	1				1	1				1	0	1					6														0	√
SOHO	1995	Jul-95	Atlas IIAS	East	IC	Planned	17085	4078	DS SOL	-	-	-	34768			1																1														0	
EOS-AM	1998	Jun-98	IC	West	IC	Planned	13554	12000	LEO POL	381	381	98.2	26452						1					1					1			3														0	
TDRS F8-F10	1998	Aug-98	IC	East	IC	Planned	27580	4905	GEO	19310	19310	0.0	38267						1	1	1											3														0	
TDRS N1-N8	2001		IC	East	IC	Potential	27580	4905	GEO	19310	19310	0.0	38267									1	1	1	1		1		1			6														0	
EOS-PM	2001	Dec-00	IC	West	IC	Planned	13885	12300	LEO POL	381	381	98.2	26452									1				1					1	3														0	
ASTROMAG	2001		IC	West	IC	Potential	25566	12566	LEO SS FM	220	220	28.5	24578									1										1														0	
CHEM	2002		IC	West	IC	Potential	12000	12000	LEO POL	400	400	90.0	26452										1					1				2														0	
IAM			IC	East	IC																		0									0														0	√
SIRTF	2003		IC	East	IC	Potential																		1								1														0	√
NAE	2004		IC	East	IC	Potential	3063	2645	LEO OTH	189	189	28.0	24592												1							1														0	
MSR	2005		IC	East	IC	Potential	32734	10221	DS MAR SUR	-	-	-	34768													2						2														0	
GENERIC DS-2	2011		IC		IC	Extrapolated	28752	10000	DS Planetary	-	-	-	34768																			0	1													1	
GENERIC GEO	2011		IC		IC	Extrapolated	27833	5000	GEO	19310	19310	0.0	38267																			0	1		1		1	1	1	1	1	1	1	1	1	11	
GENERIC LUN-2	2011		IC		IC	Extrapolated	16866	4000	LUNAR	-	-	-	34768																			0														0	
GENERIC LEO POL	2012		IC		IC	Extrapolated	13885	12300	LEO POL	381	381	98.2	26452																			0		1		1		1		1		1		1		6	
GENERIC EO-2	2014		IC		IC	Extrapolated	28123	8300	EAR OTH	31000	6000	90.0	36250																			0														0	
														0	1	2	0	0	2	2	2	3	2	3	3	3	2	1	2	0	1	29	2	1	1	1	1	2	1	2	1	2	1	2	1	18	

NAME	FY						MASS TO LEO	PLD MASS	DEST	APO	PER	INC	DELTA V	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	Total	11	12	13	14	15	16	17	18	19	20	21	22	23	Total	Change
CASSINI	1998	Oct-97	T IV/Cent	East	LC	Planned	18294	4510	DS SAT	-	-	-	34768						1													1														0	
PLUTO FLYBY	1999		LC	East	LC	Potential	32132	9934	DS PLU	-	-	-	34768							1	1											2														0	
CNM	2002		LC	East	LC	Potential	32132	9934	DS C/A	-	-	-	34768										1									1														0	
LTT	2006		LC	West	LC	Potential	8539	2204	LUN SUR	-	-	-	34768													1						1														0	
SOLAR PROBE	2010		LC	East	LC	Potential	8543	2205	DS SOL	-	-	-	34768																		1	1														0	
GENERIC DS-3	2012		LC		LC	Extrapolated	32270	10000	DS Planetary	-	-	-	34768																			0		1			1			1			1			4	
														0	0	0	0	0	1	1	1	0	1	0	0	1	0	0	0	0	1	6	0	1	0	0	1	0	0	1	0	0	1	0	0	4	

NAME	FY						MASS TO LEO	PLD MASS	DEST	APO	PER	INC	DELTA V	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	Total	11	12	13	14	15	16	17	18	19	20	21	22	23	Total	Change
TDRS	1993	Jan-93	STS/IUS	East	STS	Planned	27580	4905	GEO	19310	19310	0.0	38267	1		1																2														0	
ACTS	1993	Jul-93	STS/TOS	East	STS	Planned	30580	6025	GEO	19310	19310	0.0	38267	1																		1														0	
Other Shuttle P/L	1993		STS	East	STS		40000	40000	LEO	160	160	28.5	24579	5	9	7	8	8	7	8	8	8	8	8	8	8	8	8	8	8	8	140	8	8	8	8	8	8	8	8	8	8	8	8	8	104	√
AXAF-I	1998	Sep-98	STS	East	STS	Planned	40000	40000	LEO	160	160	28.5	24579						1													1														0	√
SSF Logistics/Crew Rot.	2000		STS	East	STS		36300	36300	LEO SSF	220	220	28.5	24579																			0														0	
														7	9	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	144	8	8	8	8	8	8	8	8	8	8	8	8	8	104	
Totals														9	16	15	9	14	17	16	19	25	19	17	17	18	15	17	14	13	16	286	16	15	14	15	15	15	14	16	15	15	15	16	15	196	482

Commercial Traffic Projection

Commercial Traffic Projection
9/20/93 Version

For Planning Purposes ONLY
Vehicle Selection Is Notional and Does NOT Imply Contracting Decisions

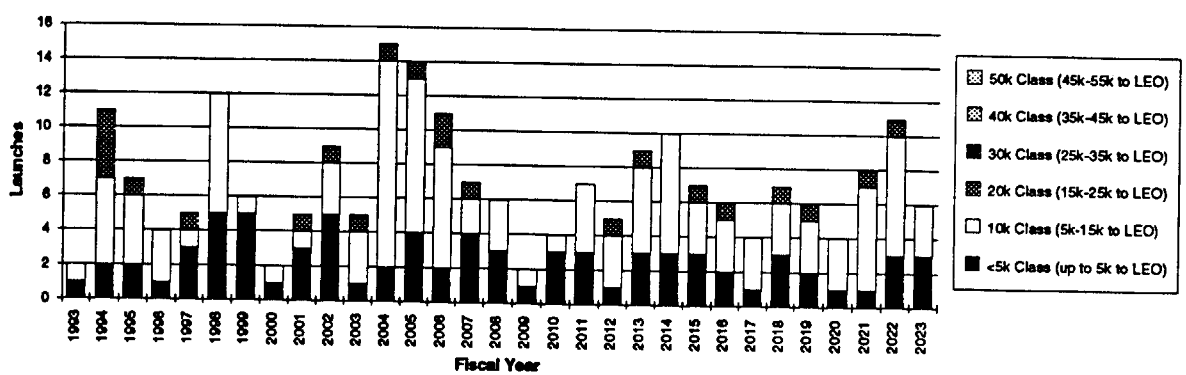
Commercial Traffic Projection, Total International Market

(Inputs)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Totals	Change
Small Class	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	33	
< 2k to GTO	0	0	3	0	1	6	5	0	6	6	5	3	6	6	5	2	4	6	7	2	3	7	3	6	3	9	5	5	2	8	9	133	
2k to 4k to GTO	2	13	10	6	1	2	1	2	0	2	2	9	6	2	2	2	0	2	3	3	3	3	3	3	3	3	3	3	3	3	3	103	
4k to 8k to GTO	5	14	10	5	5	4	2	1	2	4	5	15	9	5	3	4	2	1	5	5	8	5	5	5	5	5	5	5	5	8	5	167	
8k to 10k to GTO	1	2	3	5	2	0	0	1	2	2	2	2	3	5	2	0	0	1	1	2	2	1	2	2	1	2	2	1	2	2	1	54	
	9	31	28	17	10	13	9	5	11	15	15	30	25	19	13	9	7	11	17	13	17	17	14	17	13	20	16	15	13	22	19	490	

Commercial Traffic Projection, U.S. Capture (40%)

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Totals
<5k Class (up to 5k to LEO)	1	2	2	1	3	5	5	1	3	5	1	2	4	2	4	3	1	3	3	1	3	3	3	2	1	3	2	1	1	3	3	77
10k Class (5k-15k to LEO)	1	5	4	3	1	7	1	1	1	3	3	12	9	7	2	3	1	1	4	3	5	7	3	3	3	3	3	3	6	7	3	118
20k Class (15k-25k to LEO)	0	4	1	0	1	0	0	0	1	1	1	1	1	2	1	0	0	0	0	1	1	0	1	1	0	1	1	0	1	1	0	22
30k Class (25k-35k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40k Class (35k-45k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50k Class (45k-55k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	11	7	4	5	12	6	2	5	9	5	15	14	11	7	6	2	4	7	5	9	10	7	6	4	7	6	4	8	11	6	217

Commercial Traffic Projection



Notes:
1. Last report dated: 8/16/93, R. Brodowski, Code DN, 202-358-4494
2. Commercial model from 1993 to 1996 based on Memo: "NASA ELV Manifest and Long Range Planning Status", Code SV, August 17, 1993, K. Poniatowski
3. Commercial traffic from 1997 to 2010 provided by Office of Commercial Space Transportation/DoT, FAX dated Sept. 17, 1993; U.S. launches assume 40% capture of total international market
4. Commercial model from 2011 to 2023 average of projected flight rates from 1993 to 2010

For Planning Purposes ONLY
Vehicle Selection Is Notional and Does NOT Imply Contracting Decisions

C-2

Commercial Traffic Projection
9/20/93 Version

For Planning Purposes ONLY
Vehicle Selection is Notional and Does NOT Imply Contracting Decisions

East Coast (KSC, CCAFS) Launches

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Totals	Change
<5k Class (up to 5k to LEO)	1	0	2	1	1	1	1	1	1	3	0	1	1	1	1	2	0	1	1	0	1	1	0	1	0	1	1	0	1	1	1	28	
10k Class (5k-15k to LEO)	1	4	4	3	1	3	1	1	1	3	3	12	9	3	2	3	1	1	4	3	5	3	3	3	3	3	3	3	6	3	3	101	
20k Class (15k-25k to LEO)	0	4	1	0	1	0	0	0	1	1	1	1	1	2	1	0	0	0	0	1	1	0	1	1	0	1	1	0	1	1	0	22	
30k Class (25k-35k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
40k Class (35k-45k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
50k Class (45k-55k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	2	8	7	4	3	4	2	2	3	7	4	14	11	6	4	5	1	2	5	4	7	4	4	5	3	5	5	3	8	5	4	151	
Mass to LEO	12	120	64	32	32	32	12	12	32	56	50	142	112	72	42	34	10	12	42	50	72	32	50	52	30	52	52	30	82	52	32		

West Coast (VAFB) Launches

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Totals
<5k Class (up to 5k to LEO)	0	2	0	0	2	4	4	0	2	2	1	1	3	1	3	1	1	2	2	1	2	2	3	1	1	2	1	1	0	2	2	49
10k Class (5k-15k to LEO)	0	1	0	0	0	4	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	4	0	17
20k Class (15k-25k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30k Class (25k-35k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40k Class (35k-45k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50k Class (45k-55k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	3	0	0	2	8	4	0	2	2	1	1	3	5	3	1	1	2	2	1	2	6	3	1	1	2	1	1	0	6	2	66
Mass to LEO	0	14	0	0	4	48	8	0	4	4	2	2	6	42	6	2	2	4	4	2	4	44	6	2	2	4	2	2	0	44	4	

Total Launches

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Totals
	2	11	7	4	5	12	6	2	5	9	5	15	14	11	7	6	2	4	7	5	9	10	7	6	4	7	6	4	8	11	6	217

Notes:
1. Last report dated: 8/16/93, R. Brodowski, Code DN, 202-358-4494
2. Commercial model from 1993 to 1996 based on Memo: "NASA ELV Manifest and Long Range Planning Status", Code SV, August 17, 1993, K. Poniatowski
3. Commercial traffic from 1997 to 2010 provided by Office of Commercial Space Transportation/DoT, FAX dated Sept. 17, 1993; U.S. launches assume 40% capture of total international market
4. Commercial model from 2011 to 2023 average of projected flight rates from 1993 to 2010

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NAME	FY	Date		Site	Class		MASS TO LEO	PLD MASS	DEST	APO	PER	INC	DELTA V
SCD-1 (Brazilian)	1993	Feb-93	Pegasus	KSC		Planned							
ORBCOMM FDM	1994	Dec-93	Pegasus	VAFB		Planned							
ORBCOMM	1994		Pegasus	WFF		Planned							
GEOSAT	1995	Jun-95	Pegasus	VAFB		Planned							
GENERIC SLV	1996				SLV	Extrapolated							

NAME	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	Total	11	12	13	14	15	16	17	18	19	20	21	22	23	Total	Change
SCD-1 (Brazilian)	1																		1														0	
ORBCOMM FDM		1																	1														0	
ORBCOMM		1	1																2														0	
GEOSAT			1																1														0	
GENERIC SLV				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	1	1	1	1	1	1	1	1	1	1	1	1	13	
	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20	1	1	1	1	1	1	1	1	1	1	1	1	1	13	

NAME	FY	Date		Site	Class		MASS TO LEO	PLD MASS	DEST	APO	PER	INC	DELTA V
AFFISTAR	1995			X	SLV	Planned		1850				0.0	
AMOS	1995			K	SLV	Planned		1964					
COMET	1995			E	SLV	Planned		1800		300	300	40.0	
GENERIC Remote Sens	1997				SLV	Extrapolated							
GENERIC Little LEO Con	1998				SLV	Extrapolated							
GENERIC Big LEO Const	1999				SLV	Extrapolated							
GENERIC SLV	2011				SLV	Extrapolated							

NAME	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	Total	11	12	13	14	15	16	17	18	19	20	21	22	23	Total	Change
AFFISTAR		0	1									1							2														0	√
AMOS			1										1						2														0	
COMET			1																1														0	
GENERIC Remote Sens					1	2	1		2	2		2	2	1	1	2		2	18	3	2	3	2	2	3	2	2	3	2	2	3	2	31	√
GENERIC Little LEO Con						4	1		1	4	2			5	1		1	4	23	1			5	1		1	4	2			5	1	20	√
GENERIC Big LEO Const							3		3		3		3		3		3		18	3					3		3		3			6	18	√
GENERIC SLV																			0	0				0									0	√
	0	0	3	0	1	6	5	0	6	6	5	3	6	6	5	2	4	6	64	7	2	3	7	3	6	3	9	5	5	2	8	9	69	

NAME	FY	Date		Site	Class		MASS TO LEO	PLD MASS	DEST	APO	PER	INC	DELTA V
EUTELSAT-2	1993			K	MLV	Planned		3969					
NATO-IVB	1994	Dec-93	Delta	E	MLV	Planned		3159					
APSTAR	1994			X,E	MLV	Planned		3200					
ASIASAT	1994			E	MLV	Planned		4000					
BRAZILSAT	1994			K	MLV	Planned		3858					
BS-3N	1994			K	MLV	Planned		2400					
SAX	1995			E	MLV	Planned		2668		600	100	2.0	
DOMINION	1995		Delta	E	MLV	Planned		2970					
GALAXY-1R	1994		Delta	E	MLV	Planned							
ITALSAT	1994			E,K	MLV	Planned		3969					
MEASAT	1994			K	MLV	Planned		4000					
MSX	1994		Delta	W	MLV	Planned							
NAHUEL	1994			E	MLV	Planned		4000					
THAICOM	1994			K	MLV	Planned		2866					
UNICOM	1994			E	MLV	Planned		3597					
ARABSAT	1995			K,E	MLV	Planned		3960				19-31	
IRIDIUM	1995			W	MLV	Planned		922		785	100	90.0	
KOREASAT	1995	Apr-95	Delta	E	MLV	Planned		3528					
PACSTAR	1995			E	MLV	Planned		3087					
PALAPA-C	1995			E	MLV	Planned		4000					
SKYNET	1997			E	MLV	Potential		4000					
SATCOM	2000			E	MLV	Potential		3800					
GALAXY	2002			E	MLV	Potential		3087					
GENERIC BIG LEO CONST	1998				MLV	Extrapolated							
GENERIC MLV	2011				MLV	Extrapolated							

NAME	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	Total	11	12	13	14	15	16	17	18	19	20	21	22	23	Total	Change
EUTELSAT-2	2																		2														0	
NATO-IVB		1									1								2														0	√
APSTAR		1										1							2														0	
ASIASAT		1				1							1			1			4														0	
BRAZILSAT		2									1	1							4														0	
BS-3N		1										1							2														0	
SAX			1																1														0	
DOMINION			1	1										1					3														0	√
GALAXY-1R		1																	1														0	√
ITALSAT		1										1							2														0	√
MEASAT		1	1									1	1						4														0	
MSX		1																	1														0	√
NAHUEL		1										1							2														0	
THAICOM		1	1									1	1						4														0	
UNICOM		1	1									1	1						4														0	
ARABSAT			1	1				1										1	4														0	
IRIDIUM			0	0	0														0														0	
KOREASAT			2									1	1						4														0	√
PACSTAR			1											1					2														0	
PALAPA-C			1				1						1			1			4														0	
SKYNET					1	1									2			1	5														0	
SATCOM								1		1									2														0	
GALAXY										1									1														0	
GENERIC BIG LEO CONST				4															4														0	√
GENERIC MLV																			0	3	3	3	3	3	3	3	3	3	3	3	3	3	39	
	2	13	10	6	1	2	1	2	0	2	2	9	6	2	2	2	0	2	64	3	3	3	3	3	3	3	3	3	3	3	3	3	39	

NAME	FY	Date		Site	Class		MASS TO LEO	PLD MASS	DEST	APO	PER	INC	DELTA V
ASTRA	1993			K	ILV	Planned		5512					
DIRECTV	1993			K	ILV	Planned		6835					
HISPASAT	1993			K	ILV	Planned		4575					
INSAT-2AB	1993			K	ILV	Planned		4189					
SOLIDARIDAD	1993			K	ILV	Planned		6026					
TELSTAR	1994	Dec-93	Atlas IIAS	E	ILV	Planned		6835					
INMARSAT	1994			E	ILV	Planned		4850					
INSAT-2CE	1994			E	ILV	Planned		4410					
MSAT	1994		Atlas IIA	E	ILV	Planned		5512					
ORION	1994		Atlas IIA	E	ILV	Planned		5000					
PAS	1994			K	ILV	Planned		7430					
SAJAC	1994			E	ILV	Planned		6000					
TURKSAT	1994			E	ILV	Planned		4851					
MOBILESAT	1995			E	ILV	Planned		5500					
NSTAR	1995			K	ILV	Planned		7000					
SPACENET	1995			E	ILV	Planned		5455					
ZOHREH	1996			E	ILV	Planned		4410					
BS-4	1996			T	ILV	Potential		4410					
EUTELSAT-3	1997			E	ILV	Potential		4851					
JC-SAT	1998			K	ILV	Potential		5027					
SUPERBIRD	1999			K	ILV	Potential		5494		2580	2400		
AURORA	2000			E	ILV	Potential		4410					
ANIK-F	2001			K, E	ILV	Potential		6500					
OPTUS	2002			K	ILV	Potential		5400					
GENERIC BIG LEO CONST	1997				ILV	Extrapolated							
GENERIC ILV	2011				ILV	Extrapolated							

NAME	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	Total	11	12	13	14	15	16	17	18	19	20	21	22	23	Total	Change
ASTRA	1	1									1	1							4														0	
DIRECTV	1	1									1	1							4														0	
HISPASAT	1									1	1								3														0	
INSAT-2AB	1																		1														0	
SOLIDARIDAD	1	1									1	1							4														0	
TELSTAR		2									1	1							4														0	
INMARSAT		1	1	1	1							1	1	1	1				8														0	
INSAT-2CE		1	1	1										1					4														0	
MSAT		2										1	1						4														0	
ORION		1	1									1	1						4														0	
PAS		1	1			1						1	1			1			6														0	
SAJAC		2										2							4														0	
TURKSAT		1	1										1						3														0	
MOBILESAT			1										1						2														0	
NSTAR			2									1	1						4														0	
SPACENET			1		1								1		1				4														0	
ZOHREH			1	1									1	1					4														0	
BS-4				2										2					4														0	
EUTELSAT-3					1	2									1	2			6														0	
JC-SAT						1	1									1	1		4														0	
SUPERBIRD							1			1							1		3														0	
AURORA								1										1	2														0	
ANIK-F									2										2														0	
OPTUS										2									2														0	
GENERIC BIG LEO CONST					2							4							6			3									3		6	√
GENERIC ILV																			0	5	5	5	5	5	5	5	5	5	5	5	5	5	65	
	5	14	10	5	5	4	2	1	2	4	5	15	9	5	3	4	2	1	96	5	5	8	5	5	5	5	5	5	5	5	8	5	71	

NAME	FY	Date		Site	Class		MASS TO LEO	PLD MASS	DEST	APO	PER	INC	DELTA V
INTELSAT VII F1-5	1993			K, E	HLV	Planned		7950					
INTELSAT VIIA F6-9	1995			K	HLV	Planned		10600					
INTELSAT VIII F1-4	1995			K, E	HLV	Planned		8200					
INTELSAT F/O F1-6	2000				HLV	Potential							
GENERIC HLV	2011				HLV	Extrapolated							

NAME	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	Total	11	12	13	14	15	16	17	18	19	20	21	22	23	Total	Change
INTELSAT VII F1-5	1	2	1	1							1	2	1	1					10														0	
INTELSAT VIIA F6-9			1	2	1								1	2	1				8														0	
INTELSAT VIII F1-4			1	2	1								1	2	1				8														0	
INTELSAT F/O F1-6								1	2	2	1							1	7														0	
GENERIC HLV																			0	1	2	2	1	2	2	1	2	2	1	2	2	1	21	
	1	2	3	5	2	0	0	1	2	2	2	2	3	5	2	0	0	1	33	1	2	2	1	2	2	1	2	2	1	2	2	1	21	
Totals	9	31	28	17	10	13	9	6	11	15	15	30	25	19	13	9	7	11	277	17	13	17	17	14	17	13	20	16	15	13	22	19	213	490

DoD Traffic Projection

DoD Traffic Projection
9/20/1993 Version

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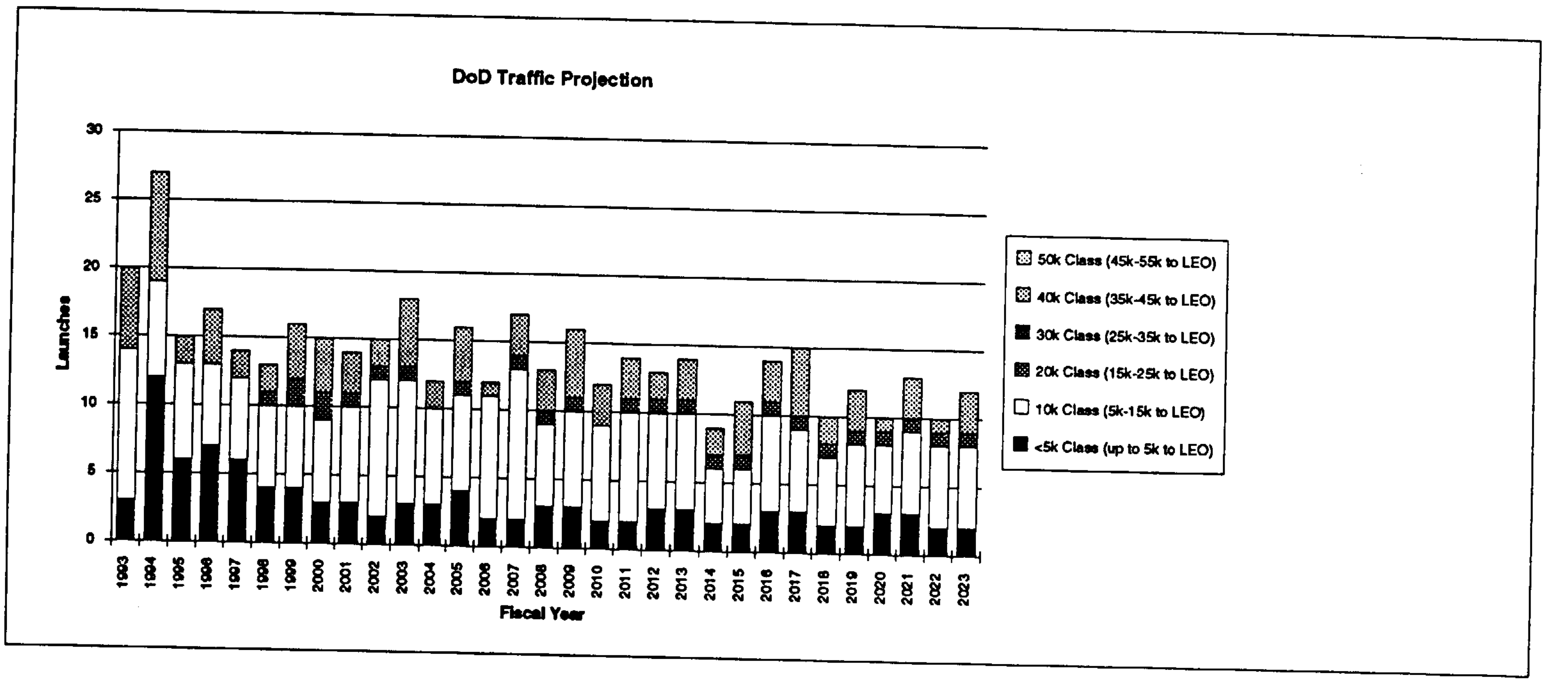
DoD Traffic

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
<5k Class (up to 5k to LEO)	3	12	6	7	6	4	4	3	3	2	3	3	4	2	2	3
10k Class (5k-15k to LEO)	11	7	7	6	6	6	6	6	7	10	9	7	7	9	11	6
20k Class (15k-25k to LEO)	0	0	0	0	0	1	2	2	1	1	1	0	1	0	1	1
30k Class (25k-35k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40k Class (35k-45k to LEO)	6	8	2	4	2	2	4	4	3	2	5	2	4	1	3	3
50k Class (45k-55k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	20	27	15	17	14	13	16	15	14	15	18	12	16	12	17	13

(FY)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Totals	Change
<5k Class (up to 5k to LEO)	3	2	2	3	3	2	2	3	3	2	2	3	3	2	2	104	
10k Class (5k-15k to LEO)	7	7	8	7	7	4	4	7	6	5	6	5	6	6	6	212	
20k Class (15k-25k to LEO)	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	25	
30k Class (25k-35k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
40k Class (35k-45k to LEO)	5	3	3	2	3	2	4	3	5	2	3	1	3	1	3	98	
50k Class (45k-55k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	16	12	14	13	14	9	11	14	15	10	12	10	13	10	12	439	



Notes:
1. Last report dated: 6/16/93, R. Brodowski, Code DN, 202-358-4494
2. DoD model FY93-20 provided by HQ AFSPACECOM, Launch Services Office; FAX "Traffic Rate Projection," September 20, 1993, Capt D. Hollenbach

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DoD Traffic Projection
9/20/1993 Version

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East Coast (KSC, CCAFS) Launches

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Totals Change
<5k Class (up to 5k to LEO)	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
10k Class (5k-15k to LEO)	11	6	6	6	6	6	5	6	7	9	9	7	6	8	9	6	7	6	7	6	6	4	4	5	5	5	5	5	5	5	5	193
20k Class (15k-25k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30k Class (25k-35k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40k Class (35k-45k to LEO)	4	5	2	2	1	1	2	3	2	2	3	2	2	1	1	3	3	3	1	2	1	2	2	3	3	2	1	1	1	1	1	63
50k Class (45k-55k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	15	12	9	9	7	7	7	9	9	11	12	9	8	9	10	9	10	9	8	8	7	6	6	8	8	7	6	6	6	6	6	259
Mass to LEO	270	262	142	142	100	100	130	180	150	170	210	150	140	120	130	180	190	180	110	140	100	120	120	170	170	130	90	90	90	90	90	

West Coast (VAFB) Launches

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Totals
<5k Class (up to 5k to LEO)	3	11	5	6	6	4	4	3	3	2	3	3	4	2	2	3	3	2	2	3	3	2	2	3	3	2	2	3	3	2	2	101
10k Class (5k-15k to LEO)	0	1	1	0	0	0	1	0	0	1	0	0	1	1	2	0	0	1	1	1	1	0	0	2	1	0	1	0	1	1	1	19
20k Class (15k-25k to LEO)	0	0	0	0	0	1	2	2	1	1	1	0	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	25
30k Class (25k-35k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40k Class (35k-45k to LEO)	2	3	0	2	1	1	2	1	1	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	35
50k Class (45k-55k to LEO)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	15	6	8	7	6	9	6	5	4	6	3	8	3	7	4	6	3	6	5	7	3	5	6	7	3	6	4	7	4	6	180
Mass to LEO	86	152	20	92	52	68	138	86	66	34	106	6	118	14	124	26	106	14	114	36	116	24	104	46	116	24	114	26	116	34	114	

Total Launches

(FY)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Totals
	20	27	15	17	14	13	16	15	14	15	18	12	16	12	17	13	16	12	14	13	14	9	11	14	15	10	12	10	13	10	12	439

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